JOURNAL OF AGRICULTURAL RESEARCH

VOL. 68 WASHINGTON, D. C., FEBRUARY, 15, 1944 No. 4

EFFECT OF FERTILIZER, SOIL COMPOSITION, AND CERTAIN CLIMATOLOGICAL CONDITIONS ON THE CALCIUM AND PHOSPHORUS CONTENT OF TURNIP GREENS [1]

By O. A. SHEETS, *associate in home economics*, L. MCWHIRTER, *assistant in home economics*, W. S. ANDERSON, *head, Department of Horticulture*, and M. GIEGER, *chief chemist, Mississippi Agricultural Experiment Station*; L. ASCHAM, formerly *home economist*, H. L. COCHRAN, *associate horticulturist*, and M. SPEIRS, *home economist, Georgia Agricultural Experiment Station*; R. REDER, *associate professor, agricultural chemistry research, Oklahoma Agricultural Experiment Station*; J. B. EDMOND, *associate horticulturist*, E. J. LEASE, *associate chemist*, and J. H. MITCHELL, *head, Department of Chemistry, South Carolina Agricultural Experiment Station*; G. S. FRAPS, *chief, Division of Chemistry*, J. WHITACRE, *chief, Division of Rural Home Research*, and S. H. YARNELL, *chief, Division of Horticulture, Texas Agricultural Experiment Station*; W. B. ELLETT, *chemist*, R. C. MOORE, *assistant horticulturist, Virginia Agricultural Experiment Station*; and H. H. ZIMMERLEY, *director, Virginia Truck Experiment Station* [2]

INTRODUCTION

Many investigations have been reported which demonstrate that environmental factors are responsible for wide variations in the composition of plants. These investigations, however, furnish little information concerning the effects of specific factors on the nutritive value of vegetables. Field studies relating to the production of vegetables have been chiefly concerned with yield and marketability of the product rather than with its nutritive value. Greenhouse studies have been conducted to determine the effects of certain environmental factors on the composition of vegetables, but the extent to which the results of such studies can be applied to field crops is questionable. Reported studies thus do not provide adequate information which might serve as a basis for recommending cultural practices designed to increase the nutritive value of food plants.

The experiments reported here were undertaken as one phase of a cooperative project to determine some of the most important factors which affect the nutritive value of vegetables. It was believed that a study in which the same varieties of vegetables were grown in different geographical areas where soil and climatic conditions varied widely would furnish information of much more value than could be obtained if the vegetables were grown in only one area. The purpose of the present study was to determine the effect of fertilizer treatments, soil composition, and certain climatological conditions on the calcium, phosphorus, and iron content of turnip (*Brassica rapa* L.) greens. The results on the calcium and phosphorus content of turnip greens are reported in this paper.

[1] Received for publication December 30, 1942. Approved for publication as Paper No. 2 by the Executive Committee of the Southern Cooperative Project, "Variations in the Composition and Nutritive Value of Vegetables Grown in the South"; Paper No. 108 from the Georgia Agricultural Experiment Station; Paper No. 65 from the Mississippi Agricultural Experiment Station; Paper No. 151 from the Oklahoma Agricultural Experiment Station; Paper No. 785 from the Texas Agricultural Experiment Station; and Paper No. 90, miscellaneous publications, from the Virginia Truck Experiment Station.

[2] Grateful acknowledgment is made to Dr. B. L. Wade, senior geneticist in charge, U. S. Regional Vegetable Breeding Laboratory, Charleston, S. C., for guidance in planning this project and for assistance in the statistical treatment of the data; to other persons whose names are not listed in the authorship, as horticulturists and chemists in the main and branch stations, for valuable assistance; and to members of the Home Economics, Chemistry, and Horticulture Departments of Texas Technological College at Lubbock, who participated in the nonfactorial experiments. Acknowledgment is also made to Dr. I. E. Miles, director of soil testing, North Carolina Department of Agriculture, for his work in carrying out the rapid soil tests.

MATERIAL AND METHODS

PLAN OF EXPERIMENTS

Two different plans have been followed in the experiments on turnip greens. In the first series of experiments the fertilizer treatment was uniform in each locality, except at two places in Texas where fertilized and unfertilized treatments were compared, and replications alone were used. This plan was changed to one of factorial design, because of the greater efficiency of the latter. The experiments will be referred to as nonfactorial and factorial experiments.

The nonfactorial experiments were conducted during the fall of 1938 in Mississippi, South Carolina, Texas, and Virginia, and continued in South Carolina in the spring of 1939. A total of 19 experiments in 12 localities were carried out. The soil was fertilized in the manner customary for the locality; the sources for nitrogen, phosphorus, and potassium were nitrate of soda, superphosphate, and muriate of potash, respectively. No other fertilizers were used. Five crops at 3 places in Texas received no fertilizer treatment. Applications of fertilizer on the acre basis at the 11 places were as follows: In Mississippi, 1,000 pounds of 6–8–4 were used at Poplarville, Natchez, and West Point, and 600 pounds of nitrate of soda at Stoneville; in Norfolk, Va., 1,000 pounds of 6–6–5; in South Carolina, 500 pounds of 4–8–4 at Edisto, 800 pounds of 4–12–4 at Clemson, and 1,000 pounds of 4–8–4 at Sandhill; in Texas, 150 pounds of 11–48–0 and no fertilizer at Winter Haven, 200 pounds of 6–12–6 and no fertilizer at College Station, and no fertilizer at Iowa Park, or at Lubbock. The plantings consisted of 20 rows, 20 feet long, of which the inner 10 rows 10 feet long were harvested for sampling. Each row constituted a separate sample.

The factorial experiments were conducted during the spring and fall of 1939 and 1940. A total of 30 experiments in 19 localities situated in Georgia, Mississippi, Oklahoma, South Carolina, Texas, and Virginia, were carried out. A $2 \times 2 \times 2 \times 2$ factorial design was used consisting of 16 treatments with 2 replications in each experiment. The 4 fertilizer factors, nitrogen, phosphorus, potassium, and calcium, were studied in all combinations of high and low levels. The check or natural untreated soil constituted the low level for each of the 4 nutrients. The treatments were as follows: NPKCa, NPK, NPCa, NP, NKCa, NK, NCa, N, PKCa, PK, PCa, P, KCa, K, Ca, and check. The acre rates and materials used were: 60 pounds of N from ammonium sulfate, 60 pounds of P_2O_5 from triple superphosphate, 60 pounds of K_2O from muriate of potash, 120 pounds of Ca from gypsum.

The standard procedure for the factorial experiments was to grow single-row plots 25 feet long and not less than 30 inches apart.[3] The 16 treatments were randomized in a single block with at least 1 guard

[3] Since the fertilizer was applied in single-row plots, the possibility of cross-feeding between adjacent rows was considered. Weaver and Bruner (*27*)[4] report the maximum length of any lateral root attained by turnips in Kansas after 111 days through midsummer was 30 inches. This growth period was equalled in only one instance (at Blacksburg, Va., 110 days) under much more favorable moisture conditions. Under similar conditions of moisture at Geneva, N. Y., Goff (*13*) observed horizontal roots no longer than 18 inches. Moisture conditions, growth period, and distance between treatments were thus unfavorable for cross-feeding. In addition, the clean cultivation given the plots discouraged the development of long lateral roots. General observation of the wide difference in growth response of various annual crops on adjacent fertilized and unfertilized rows greatly strengthens the assumption that there can be little cross-feeding under such circumstances. This was noted especially for those plots lacking nitrogen at many locations east of the Mississippi River.

[4] Italic numbers in parentheses refer to Literature Cited p. 189.

row on each side. A duplicate block with a different arrangement of treatments was grown, usually adjacent to the first, but in some cases it was necessary to separate the 2 blocks to secure uniformity of growing conditions. The fertilizer was applied in a band 2 inches to the side and 1 inch below the seed level.

GROWING THE CROP

The Seven Top variety of turnip was chosen because it represents a type that is grown primarily for greens rather than for the root. It is well adapted and makes a good growth under favorable conditions over the entire region included in this study. A uniform lot of seed was supplied by the United States Regional Vegetable Breeding Laboratory at Charleston, S. C.

The extent of the region covered by the cooperating States provided opportunity to grow greens under a wide variety of soil types, rainfall, and temperature. Soils typical of each area were selected for the experiment. Each site was chosen as being representative of home-garden conditions at each location. When crops were grown for successive seasons in the same locality, planting was not made twice on the same site, but on one nearby having the same kind of soil. The places where greens were grown and the average annual precipitation in inches for each site are shown in figure 1.[5] The cultural history for the locations is summarized in table 1. The soil types, given for each location in table 2, ranged from the comparatively deep Norfolk fine sand of the Sandhill section of South Carolina to the Houston clay-loam of northeastern Mississippi. The following great soil groups are represented: Gray-Brown Podzolic soils, Red and Yellow Podzolic soils, Reddish Chestnut soils, Reddish-Brown soils, Rendzina soils, and Ground-Water Podzolic soils. Records of the rainfall and temperature during the growing season at each locality are shown in table 3.

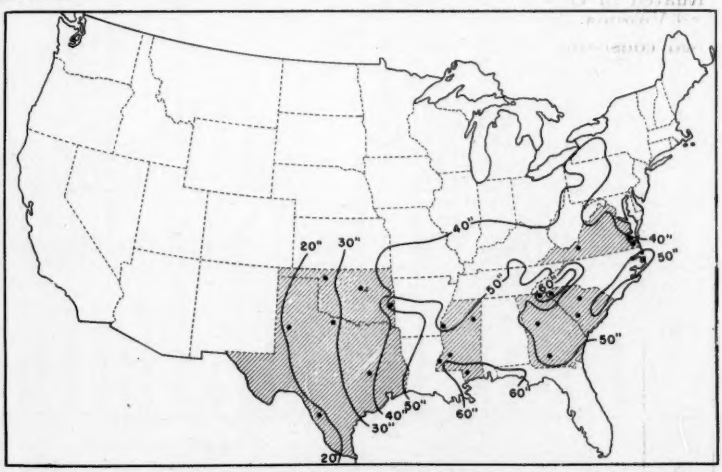

FIGURE 1.—Average annual precipitation in inches for the 20 places in which turnip greens were grown.

[5] See KINCER, J. B. PRECIPITATION AND HUMIDITY, *In* Baker, O. E., Atlas of American Agriculture, pp. 6, 7. Illus. 1922.

TABLE 1.—*Location and recent cultural history of sites where turnip greens were grown*

State	Location	Year	Crop or cultural treatment	Commercial fertilizer [1]	Barnyard manure	Green manure
					Tons	
Georgia	Blairsville	1929	Lettuce	800 pounds 8-8-6		Winter rye and vetch.
		1940	Potatoes	do		Austrian winter peas.
	Experiment	1938	Tomatoes	do	10–20	Winter rye and vetch.
		1940	Pimientos	600 pounds 8-8-6	10–20	Do.
	Tifton	1939	Peanuts	300 pounds 4-8-10		Winter cover of crotalaria.
Mississippi	Crystal Springs	1939	Miscellaneous vegetable crops	Complete fertilizer		
		1940	do	do		
	Natchez	1936	Tomatoes	1,000 pounds 4-8-4		
		1937	Watermelons	do	8–10	
		1938	Cabbage	do		
	Poplarville	1933–38	Winter oats (followed by cowpeas or soybeans for hay).			
		1935–36	Soybeans		12–15	
		1937–38	Tomatoes (followed by nonfactorial experiments)			
	Stoneville	1937	Sweetpotatoes			
		1938–39	Spring crop of potatoes (followed by factorial experiment).	100 pounds ammonium sulfate		
		1939	Summer eggplant (followed by factorial experiments).	do		
	West Point	1934–37	Alfalfa	300 pounds 18 percent superphosphate.		
		1938	Corn			
Oklahoma	Heavener	1939	Corn	Phosphate		
		1940	Mung beans			
	Perkins		Fallow			
	Woodward	1939	Dwarf milo, cowpeas			
		1940	Wheat			
South Carolina	Clemson	1936–37	Asparagus seedlings			
		1938	Fallow			
	Edisto	1938	Cantaloupes	1,000 pounds 5-10-5		
		1939	Okra	400 pounds 5-7-5		
	Sandhill	1938	Watermelons	500–700 pounds 4-8-4		
		1939	Rye (followed by nonfactorial experiment)	do		
		1939–40	Fallow (followed by factorial experiment)			
Texas	College Station	1938	Tomatoes	300 pounds 6-12-6		Winter oats.
		1940	Squash	do		
	Iowa Park	1938	Garden			
	Lubbock	1933–38	Trees and shrubs (nursery)			
		1938	General vegetable crop			
	Winter Haven	1938	English peas			
		1939	Spinach			
		1940	Sugar beets			
Virginia	Blacksburg	1935–40	Grass			
	Norfolk	1939	Strawberries	No residual effect		
		1940	Spinach	Residual effect of N		

[1] No lime had been applied to any site with the exception of that at Sandhill where there had been applications of 1,000 to 1,500 pounds per acre.

TABLE 2.—*Data on composition of soil samples taken from turnip-green plots of the factorial experiments*

* No lime had been applied to any site with the exception of that at Sandhill where there had been applications of 1,000 to 1,500 pounds per acre.

TABLE 2.—*Data on composition of soil samples taken from turnip-green plots of the factorial experiments*

Experiment No.	State	Location	Year	Soil type	pH value	Calcium [1]	Phosphorus [1]	Magnesium [1]	Organic matter	Total exchange capacity [2]	Exchangeable calcium [2]
									Percent	*Milliequivalents*	*Milliequivalents*
1	Georgia	Blairsville	1939	Congaree sandy loam	5.5	M−	T+	T+	3.43	13.9	3.4
2	do	do	1940	do	5.6	H	L−	T	4.00	17.4	4.1
3	do	Experiment	1939	Cecil sandy clay loam	5.3	T+	L+	L−	3.21	6.7	1.9
4	do	do	1940	do	5.8	L	L+	L−	1.92	6.3	3.8
5	do	Tifton	1939	Norfolk sandy loam	5.6	T	L+	L−	1.93	3.2	1.7
6	Mississippi	Crystal Springs	1939	Grenada silt loam	5.4	L	M	M	1.22	5.4	1.1
7	do	do	1940	do	4.8	L	L−	M	1.33	9.0	1.7
8	do	Natchez	1939	Memphis silt loam							
9	do	Poplarville	1939 [3]	Ruston fine sandy loam	5.4	T	L+	L−	1.07	3.8	.9
10	do	do	1939	do	5.4	T+	L	M−	.68	5.0	1.9
11	do	do	1940	do	5.1	T	L−	L	1.07	4.0	.8
12	do	Stoneville	1939	Sarpy loam	7.0	H	H	H	1.36	9.8	3.5
13	do	do	1940	do	6.8	H	H	H	1.55	10.9	4.9
14	do	West Point	1939	Houston clay loam	7.8	H+	L−	H+	1.76	34.3	30.0
15	Oklahoma	Heavener	1939	Hanceville fine sandy loam	6.1	M−	T+	M	1.00	3.8	2.8
16	do	Perkins	1939	Canadian loamy fine sand	5.1	L	L−	M	1.30	6.2	2.7
17	do	do	1940	do	6.0	M+	L−	M+	1.35	5.5	2.8
18	do	Woodward	1939	Pratt fine sandy loam	6.6	H	L+	H	1.20	5.0	4.6
19	do	do	1940	Weymouth very fine sandy loam	7.4	H	L+	H	1.78	13.1	10.9
20	do	do.[4]	1940	do	7.6	H	L+	H	1.40	10.1	8.0
21	South Carolina	Clemson	1939	Lloyd clay loam	6.3	H−	L+	M	1.01	4.7	1.6
22	do	Edisto	1939	Marlboro sandy loam	5.7	L−	L+	M−	1.42	3.5	1.7
23	do	Sandhill	1940	Norfolk fine sand	5.5	T	L+	L	1.00	2.0	.9
24	Texas	College Station	1940	Lufkin fine sandy loam	5.4	M	M−	M	.48	5.5	2.9
25	do	Iowa Park	1939	Yahola loamy very fine sand	8.6	H	M−	H	.84	7.9	11.8
26	do	Winter Haven	1939	Orelia clay loam	7.2	H	L+	H	1.29	12.2	3.9
27	do	do	1940	do	7.7	H	M+	H	.84	7.8	5.4
28	Virginia	Blacksburg	1940	Dunmore silt loam	5.5	T+	L	L−	2.42	7.2	1.6
29	do	Norfolk	1939	Keyport sandy loam	5.8	L−	L+	L	2.47	7.6	2.3
30	do	do	1940	do	6.9	H	L+	M	2.65	7.1	3.7

[1] T (trace)=0–300 pounds Ca, 0–10 pounds P, and 0–10 pounds Mg per acre; L (low)=300–1,000 pounds Ca, 10–50 pounds P, and 10–30 pounds Mg per acre; M (medium)=1,000–2,000 pounds Ca, 50–100 pounds P, and 30–90 pounds Mg per acre; H (high)=2,000–3,000 pounds Ca, 100–250 pounds P, and 90–150 pounds Mg per acre; H+ (very high)=3,000–4,000 pounds Ca, 250–400 pounds P, and 150–200 pounds Mg per acre.

[2] Milliequivalents per 100 gm. of soil.

[3] Spring crop.

[4] Irrigated plots.

TABLE 3.—*Mean temperatures and rainfall for the growing periods of the turnip-green crops for the years 1938, 1939, and 1940*

Location	1938 crops				1939 crops				1940 crops			
	Growing period	Average temperature		Rainfall	Growing period	Average temperature		Rainfall	Growing period	Average temperature		Rainfall
		Maximum	Minimum			Maximum	Minimum			Maximum	Minimum	
		°F.	°F.	*Inches*		°F.	°F.	*Inches*		°F.	°F.	*Inches*
Georgia:												
Blairsville					Mar. 6–June 8	74.8	48.6	10.32	Apr. 29–June 8	80.5	50.5	5.46
Experiment					Mar. 28–June 16	78.8	57.2	11.11	Aug. 27–Oct. 7	85.2	61.8	4.67
Tifton					Feb. 20–May 8	73.1	53.3	17.94				
Mississippi:												
Crystal Springs					Sept. 15–Nov. 20	77.2	53.4	5.67	Mar. 11–May 10	72.3	49.4	14.28
Natchez	Sept. 17–Nov. 23	82.2	54.5	6.47	Mar. 22–May 10	79.1	53.4	9.88				
Poplarville	Sept. 6–Nov. 25	82.4	58.2	7.85	Feb. 7–May 8	82.6	59.8	4.42	Feb. 21–Apr. 26	73.2	50.2	11.38
Stoneville	Sept. 10–Nov. 25	82.3	53.3	2.83	Sept. 12–Nov. 7	82.6	60.8	4.42				
West Point	Aug. 29–Nov. 15	82.7	54.1	3.44	Oct. 2–Nov. 14	75.8	49.1	4.12	Feb. 27–Apr. 22	70.3	46.4	9.46
Oklahoma:					Mar. 16–May 18	75.0	50.1	8.76				
Heavener					Mar. 18–May 14	75.2	49.4	11.05				
Perkins					Apr. 17–May 26	80.0	51.4	5.59	May 6–June 29	83.7	59.6	5.41
Woodward					Mar. 31–May 28	78.7	51.5	5.87	Apr. 29–June 8	82.3	56.6	2.59
South Carolina:									Apr. 29–June 13	82.2	56.6	[1] 3.23
Clemson	Aug. 15–Oct. 21	83.0	59.2	4.30	Apr. 17–June 24	81.1	59.7	8.32				
					Aug. 14–Oct. 30	84.8	58.9	8.35				
Edisto	Sept. 5–Oct. 21	82.4	60.4	5.20	Mar. 18–Apr. 25	74.6	51.3	2.21				
					Sept. 12–Oct. 25	84.9	62.3	2.97				
Sandhill	Sept. 10–Nov. 15	77.6	56.6	3.83	Mar. 15–May 3	73.4	51.7	2.82	Apr. 1–May 27	77.3	53.2	3.70
Texas:												
College Station	Sept. 16–Nov. 11	86.4	55.5	3.54					Sept. 14–Nov. 7	84.2	58.4	5.48
Iowa Park	Sept. 5–Nov. 8	85.6	[1] 3.91		Aug. 25–Nov. 13	82.5	57.7	4.88				
Lubbock									Mar. 14–June 6	85.7	33.0	19.74
Winter Haven	Oct. 5–Dec. 1	82.1	53.1	[1] .08	Nov. 10–Jan. 18	68.5	44.2	[1] 2.94	Oct. 4–Nov. 19	80.4	55.7	[1] 2.00
Virginia:												
Blacksburg									May 8–June 19	65.3	42.6	10.20
Norfolk	Sept. 12–Dec. 12	70.4	50.4	13.64	Aug. 18–Oct. 30	81.9	62.1	9.56	Aug. 14–Sept. 29	81.2	63.6	10.77

[1] Plots received irrigation in addition to recorded rainfall.

The greens were given the cultivation common to good garden procedure, which did not vary much among the different locations. This involved adequate preparation of the seedbed with turning plow, disk, and harrow, and subsequent cultivation and hoeing to keep down weeds. Seeding was comparatively heavy to insure a good stand. It was sometimes necessary to water the fall crop early in the season to get it started. All crops were grown under irrigation at Winter Haven and at Iowa Park, Tex., and one crop at Woodward, Okla.

The use of insecticides was avoided as far as possible and dusts or sprays containing copper or calcium were not used. In cases where aphids or other leaf insects made their appearance late in the season, no control measure was employed. No insects were observed on the plantings in Mississippi and Oklahoma. It was necessary to use rotenone dust for flea beetles at Winter Haven in 1938 and at Iowa Park the following year, early in the growing season. Aphids were found later in the season at other places, but were not serious except at Experiment, Ga., where they appeared earlier, and were controlled by syringing with a garden hose and the use of a soft brush.

SOIL ANALYSIS

Samples of soil for analysis were taken from the sites before treatment. The determinations carried out on each sample and the methods used were as follows: The pH value was estimated electrometrically, using a glass electrode; organic matter by the Schollenberger method or modifications of it (*24*, *1*, *22*); exchange capacity by the Schollenberger and Dreibelbis methods (*25*); and exchangeable calcium by the Association of Official Agricultural Chemists method (*5*). Calcium, phosphorus, and magnesium were determined by rapid soil tests as used in the North Carolina Soils Testing Laboratory (*15*).[6]

PLANT ANALYSIS

Collection and Preparation of Samples

The turnip greens were harvested when they were at a good marketable stage, but the length of the growing period varied in different localities (table 3). In the majority of instances all of one crop was harvested in 1 day. The greens were handled as soon as possible after harvesting. A random or a representative sample from each of the 32 plots (16 treatments replicated) was selected for analysis, and damaged leaves or those which would be unfit for cooking were discarded. The petioles of the leaves were cut or broken off about three-fourths of an inch above the crown of the root, and the greens were then sorted and thoroughly washed 3 to 6 times in tap water, or until they were free from soil, and finally washed in distilled water. The excess moisture was drained off, and in some instances there was a preliminary drying in a clean dust-free room before the samples were placed in the oven. A Freas electric oven with a forced draft was used in 4 of the 6 laboratories, and the samples were dried at about 100° C. They were then ground in a ball mill equipped with porcelain jars and flint pebbles, and stored in Mason jars or glass bottles with plastic screw tops.

Duplicate fresh moisture samples were taken from each of the 32 lots of turnip greens in every crop, at the time the samples were being

[6] Miles, I. E. Buffered perchloric acid method of soil testing. [Unpublished data.]

prepared for analysis. Either randomized plants or leaves, or selected plants, were used. The samples were handled and washed in the same manner as the samples used for analysis. After washing they were spread out and allowed to dry until all visible moisture had disappeared, but they were not allowed to wilt. They were weighed, dried at a temperature of 100° C. or less, placed in aluminum moisture dishes with covers, and dried to constant weight ±0.2 gm. at 100°. A "trip" balance was used in most instances.

For moisture determinations on the stored samples, duplicate 2-gm. samples were weighed into small aluminum moisture dishes with covers. The samples were dried for 5 hours at 100° to 102° C., cooled in a desiccator, and weighed.

Methods of Analysis

Methods of the Association of Official Agricultural Chemists were used for both calcium (*3, p. 104*) and phosphorus (*4, p. 21*) determinations, with minor variations in the procedures among the different analysts. The samples were ashed according to the A. O. A. C. method (*4, p. 121*).

Since each State was responsible for the analysis of its own samples, the calcium and phosphorus analyses were made by a number of chemists. For this reason, it seemed advisable to carry out referee work among the different analysts. Accordingly, six composite samples of dried turnip greens were analyzed in duplicate by seven chemists. The statistical analyses of referee data showed conclusively that the value of interaction, laboratory × sample, for both calcium and phosphorus was too small to vitiate the results of the factorial experiments.

NONFACTORIAL EXPERIMENTS

The average calcium and phosphorus content of 10 plots (rows) of turnip greens from each of the 19 nonfactorial experiments, 17 of which were compared on the basis of standard error of the mean (*19*), is shown in table 4. It is evident from an examination of the data that there were marked differences in both the calcium and phosphorus content of the greens grown at different places. The range for calcium was from 1.814 to 4.318 percent and that for phosphorus from 0.3456 to 0.6797 percent. The variations in calcium were greater than those for phosphorus. Thus there were 5 experiments, in which the calcium content was significantly different from that of all other places. For phosphorus this was true only of 1 experiment.

While many factors were probably responsible for variations in the calcium and phosphorus content of the greens, the data indicate that differences within a location occurred as a result of season, fertilizer treatment, and size of the plant. The effect of season is shown by the results of the experiments at Edisto, Clemson, and Sandhill. There were significant seasonal differences when the greens were grown at the same place. In two of the three places, the spring greens contained more calcium and more phosphorus than the fall greens. At Edisto, however, the fall greens had a higher calcium content, and at Sandhill, a higher phosphorus content than the spring greens. There was a significant difference in both the calcium and phosphorus content between greens grown on fertilized and those grown on unfertilized

TABLE 4.—*Calcium and phosphorus content of turnip greens from 19 nonfactorial experiments, 17 [1] of which were compared on the basis of standard error of the mean*

Experiment No.	State	Location	Season	Calcium				Phosphorus			
				Average content, 10 plots (dry basis)	Standard deviation	Standard error of mean	Significantly different from all experiments except Nos. —	Average content, 10 plots (dry basis)	Standard deviation	Standard error of mean	Significantly different from all experiments except Nos. —
				Percent				*Percent*			
1	Mississippi	Natchez	Fall, 1938	2.863	0.118	0.037	7, 14, 17	0.6080	0.0227	0.0072	3, 6, 7, 12, 17, 18.
2	do	Poplarville	do	2.433	.081	.026	[2]	.5696	.0373	.0118	7, 8, 10, 11, 12, 17, 19.
3	do	Stoneville	do	2.206	.120	.038	19	.6300	.0346	.0109	1, 12, 13, 18.
4	do	West Point	do	4.318	.231	.073	[2]	.4360	.0297	.0094	5.
5	South Carolina	Clemson	do	2.655	.041	.013	8, 9, 18	.4430	.0223	.0071	4.
6	do	do [3]	Spring, 1939	3.321	.091	.029	12	.5958	.0261	.0083	1, 2, 7, 12, 17, 18.
7	do	do [4]	do	2.886	.051	.016	1, 14	.5987	.0123	.0039	1, 6, 12, 17, 18.
8	do	Edisto	Fall, 1938	2.696	.046	.015	5, 17	.5641	.0140	.0044	2, 10, 11, 12.
9	do	do	Spring, 1939	2.624	.053	.017	5, 18	.6797	.0044	.0014	13.
10	do	Sandhill	Fall, 1938	1.814	.040	.013	[2]	.5653	.0146	.0046	2, 8, 12.
11	do	do	Spring, 1939	1.960	.026	.008	[2]	.5490	.0183	.0058	2, 8, 19.
12	Texas	College Station [5]	Fall, 1938	3.317	.201	.063	6	.6004	.0544	.0172	1, 2, 3, 6, 7, 8, 10, 17, 18.
13	do	do	do	3.039	.144	.046	[2]	.6688	.0657	.0208	3, 9, 18.
14	do	Iowa Park [5]	do	[6] 2.850	.216	.048	1, 7, 17	[6] .3456	.0536	.0120	[2].
15	do	Lubbock [5]	Fall, 1939	[1] 2.920				[1] .4510			
16	do	do [5]	Spring, 1940	[1] 3.241				[1] .4832			
17	do	Winter Haven [5]	Fall, 1938	2.753	.126	.040	1, 8, 14	.5894	.0274	.0087	1, 2, 6, 7, 12.
18	do	do	do	2.617	.104	.033	5, 9	.6351	.0622	.0197	1, 3, 6, 7, 12, 13.
19	Virginia	Norfolk	do	2.100	.159	.050	3	.5418	.0186	.0059	2, 11.

[1] Lubbock submitted 1 composite sample from 10 plots for each year and is, therefore, not included in the statistical analyses.
[2] No exceptions.
[3] Only plants with small leaves were analyzed; large and small plants from Clemson were from same plot.
[4] Only plants with large leaves were analyzed.
[5] Nonfertilized plots.
[6] Average of 20 plots.

plots at Winter Haven and College Station. The greens from the fertilized plots contained less calcium but more phosphorus than did those from the nonfertilized plots. The small plants at Clemson were significantly higher in calcium than the large plants, but there was no significant difference in their phosphorus content.

The data from Lubbock were not included in the statistical analysis since there was only 1 composite sample from the 10 plots for each of the 2 years during which the turnip greens were grown. The results for both calcium and phosphorus were, however, comparable to the average results from other places.

FACTORIAL EXPERIMENTS

The analysis of variance (*11*) was applied to the data from the 30 factorial experiments. The interaction of block × treatments was the error item used. The method devised by Yates (*30*) for the analysis of factorial experiments was used to determine the effects of the fertilizer treatments. It will be noted that in the tables of factorial experiments, both simple averages and effects are given. These effects are the answers to algebraic equations in which the entire set of data is used for each effect (*23*). In each case the effects are for 8 times as many observations as the simple averages. Consequently, where apparent conflicts occur, more reliance can be placed upon the effects than upon the simple averages. Main effects, i. e., those of N, P, K, and Ca, correspond quite well with the treatments, but a word of caution is necessary in connection with the interactions. For instance, in the summation of 29 experiments given in table 7, both N and P treatments give a decrease in calcium content in comparison with the check. The effects are negative. If N and P give a decrease in calcium content, then it is to be expected that the combination NP would give a decrease. This is shown to be true in case of the N, P, and NP treatments, and the value of −0.037 for the interaction effect of NP is in addition to the decreasing effect shown by N and by P as main effects. (Interactions between 2 factors are called first-order interactions; between 3, second-order; and between 4, third-order. The most emphasis is placed on first-order interactions, since those of higher order are difficult to interpret. With one exception the latter, therefore, are not discussed).

Twenty-nine of the experiments were combined for a study of the total effects. Chi-square tests were applied and the experiments grouped according to their homogeneity. The low-error groups were used to study the causes of variability in the calcium and phosphorus content of the greens, because those groups included the majority of the experiments and because the variation not accounted for was smallest in these groups. The 29 experiments and the low-error groups were divided into subgroups for the purpose of studying the relations between the soil constituents and fertilizer treatments as they influence the mineral content of the greens.

CALCIUM

The average calcium content of the turnip greens from duplicate plots, the mean percent, and the standard deviation for each experiment are given in table 5. The range for the mean percent of calcium in the 30 experiments was from 1.74 to 5.076. The greens grown at

TABLE 5.—*Calcium content of turnip greens grown by a factorial design of 16 duplicate fertilizer treatments in 30 experiments*

TABLE 5.—*Calcium content of turnip greens grown by a factorial design of 16 duplicate fertilizer treatments in 30 experiments*

Experiment No.	Location	Year	Average content of calcium (dry basis) from duplicate plots fertilized with—																Mean	Standard deviation	Odds of—	
			NPKCa	NPK	NPCa	NP	NKCa	NK	NCa	N	PKCa	PK	PCa	P	KCa	K	Ca	Check			19:1	99:1
	Georgia:		*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*			
1	Blairsville	1939	2.035	2.110	2.120	2.060	2.525	2.690	2.480	2.465	3.535	4.375	4.170	4.240	4.570	3.590	3.615	4.085	3.167	0.422	0.899	1.242
2	....do	1940	2.590	2.360	2.935	2.650	3.015	3.115	3.540	3.325	3.265	2.975	2.940	2.930	3.225	3.370	3.125	3.160	3.033	.187	.399	.552
3	Experiment	1939	2.295	2.130	2.165	2.380	2.060	2.030	2.210	1.965	3.020	2.805	2.730	2.635	2.860	2.930	2.715	2.545	2.467	.392	.834	1.154
4	....do	1940 [1]	2.800	2.780	2.740	2.835	2.670	2.665	2.835	2.610	2.995	2.850	2.930	2.950	2.925	3.090	2.730	2.705	2.819	.098	.209	.288
5	Tifton	1939	2.230	2.170	3.005	3.045	2.715	2.460	3.270	3.045	2.805	2.655	3.035	2.635	2.630	2.615	2.835	2.475	2.727	.199	.424	.588
	Mississippi:																					
6	Crystal Springs	1939 [1]	1.855	1.700	1.940	1.715	1.815	1.770	1.840	1.655	2.245	2.130	2.150	2.255	2.330	2.205	2.105	2.185	1.997	.144	.305	.424
7	....do	1940	1.530	1.680	1.490	1.515	1.540	1.660	1.555	1.740	2.730	2.510	2.705	2.725	2.630	2.755	2.610	2.680	2.128	.197	.421	.583
8	Natchez	1939	2.655	2.935	2.780	2.790	2.880	2.820	2.690	2.785	3.385	3.125	3.435	3.720	3.565	3.075	3.395	3.095	3.071	.310	.662	.914
9	Poplarville	1939	2.180	1.890	2.470	2.330	2.180	1.995	2.460	2.335	2.610	2.495	2.605	2.285	2.500	2.325	2.260	2.510	2.402	.327	.696	.964
10	....do	1939 [1]	2.005	1.975	2.090	1.930	1.980	1.960	2.010	2.010	2.320	2.215	2.280	2.245	2.310	2.280	2.130	2.245	2.124	.126	.269	.371
11	....do	1940	1.790	1.765	1.880	1.805	1.835	1.740	1.765	1.755	2.525	2.160	1.745	2.170	2.480	2.015	2.245	2.195	1.992	.209	.444	.614
12	Stoneville	1939 [1]	2.660	2.795	2.780	2.995	3.020	2.820	3.005	2.920	2.645	2.665	2.750	3.100	2.805	2.715	2.705	2.865	2.828	.268	.571	.789
13	....do	1940	2.520	2.695	2.145	2.560	2.570	2.555	2.495	2.400	3.625	3.335	3.385	3.130	3.245	3.200	3.070	3.085	2.876	.113	.240	.334
14	West Point	1939	4.745	4.380	4.880	4.805	4.915	5.000	5.175	5.215	5.365	5.045	4.980	4.885	5.520	5.375	5.545	5.380	5.076	.178	.385	.523
	Oklahoma:																					
15	Heavener	1939	3.152	3.214	3.400	3.212	3.338	3.343	3.342	3.532	3.697	3.737	3.886	3.798	3.656	3.800	3.566	3.550	3.514	.117	.249	.348
16	Perkins	1939	2.265	2.730	2.475	2.635	3.035	2.420	2.615	2.305	2.985	3.080	2.665	2.940	2.840	2.445	2.920	2.435	2.674	.346	.738	1.021
17	....do	1940	2.665	2.810	2.975	2.920	2.840	2.940	2.870	2.905	3.070	3.145	3.125	3.205	2.915	3.095	3.035	2.960	2.967	.160	.342	.472
18	Woodward	1939	2.876	2.882	2.771	2.903	3.056	2.831	2.904	3.015	3.390	3.361	3.335	3.331	3.736	3.616	3.236	3.430	3.167	.191	.410	.569
19	....do	1940	3.240	2.903	3.205	3.265	3.215	3.191	3.190	2.890	3.270	3.249	3.443	3.384	3.322	3.159	3.398	3.525	3.240	.170	.362	.501
20	....do [2]	1940	3.296	3.280	3.272	3.158	3.316	3.169	3.361	3.313	3.822	3.780	3.609	3.487	3.692	3.511	3.604	3.671	3.459	.137	.291	.404
	South Carolina:																					
21	Clemson	1939 [1]	3.155	3.200	2.970	3.110	3.040	3.015	2.835	2.980	3.300	3.415	3.040	3.025	3.205	3.390	3.170	3.095	3.121	.147	.314	.430
22	Edisto	1939 [1]	2.750	2.175	2.420	2.535	2.525	2.485	2.855	2.595	3.030	2.605	2.430	2.370	2.805	2.710	2.795	2.575	2.604	.181	.387	.535
23	Sandhill	1940	1.550	1.385	1.390	1.545	1.785	2.195	1.615	1.465	1.895	2.060	1.605	1.585	2.035	2.005	1.765	1.955	1.740	.204	.436	.602
	Texas:																					
24	College Station	1940 [1]	2.410	2.440	2.145	2.535	2.225	2.490	2.375	2.370	2.640	2.640	2.915	2.710	2.550	2.670	2.650	2.665	2.527	.148	.314	.436
25	Iowa Park [3]	1939 [1]	2.428	2.345	2.515	2.562	2.343	2.689	2.048	2.168	3.019	2.724	2.726	2.696	2.194	2.308	2.526	2.458	2.484	.251	.758	1.047
26	Winter Haven	1939 [1]	2.294	2.209	2.256	2.192	2.314	2.135	2.320	2.237	2.508	2.349	2.490	2.419	2.498	2.343	2.495	2.322	2.336	.152	.325	.450
27	....do	1940 [1]	2.275	2.145	2.085	1.975	[4] 2.145	1.960	2.035	2.190	2.275	2.510	2.235	2.245	2.420	2.345	2.315	2.260	2.213	.229	.489	.676
	Virginia:																					
28	Blacksburg	1940	3.260	2.690	3.400	2.900	3.210	2.750	3.430	2.750	3.250	3.170	3.295	3.180	3.525	2.940	3.075	3.095	3.120	.240	.512	.707
29	Norfolk	1939 [1]	2.305	2.025	1.785	2.105	2.375	1.865	2.355	2.065	2.550	2.160	2.120	2.605	2.360	2.240	2.560	3.080	2.285	.425	.905	1.253
30	....do	1940 [1]	2.625	2.455	2.740	2.680	2.690	1.795	2.875	2.565	2.715	2.530	2.770	2.745	2.740	2.745	2.895	2.740	2.707	.141	.303	.416

[1] Fall crops. Undesignated crops were grown in the spring.
[2] Plots were irrigated.
[3] Iowa Park plots were not replicated; hence the mean is an average of 16 plots.
[4] Calculated result for 1 missing plot.

Sandhill contained the least calcium and those at West Point the most. The significant effects of each of the 16 fertilizer treatments for all experiments are shown in table 6. The effects were compared on the basis of standard error of the mean. Thirteen treatments had a significant effect upon the calcium content of the turnip greens in 1 or more experiments. There were no significant interaction effects for the treatments NKCa and KCa in any experiment. There were no fertilizer treatments that gave a significant effect at Stoneville, fall of 1939, and Norfolk, fall of 1940. It is interesting to note, however, that at Stoneville, spring of 1940, 6 treatments gave significant effects. This is the largest number of significant effects for any one place.

Of the 4 fertilizer factors studied, nitrogen had the greatest effect. It decreased the calcium content of the greens in all experiments except those at Stoneville, fall of 1939, and at Tifton. The decrease was significant in 24 of the 30 experiments. The average depression of calcium by nitrogen was approximately 0.36 percent (table 7). Applied calcium significantly increased the calcium content of the greens in 4 of the 30 experiments; namely, at Poplarville, spring of 1939; Edisto, fall of 1939; Winter Haven, fall of 1939; and Blacksburg, spring of 1940. The effect for calcium was positive in 20 experiments, with an average increase of 0.060 percent (table 7). There was a tendency for applied phosphorus to decrease the calcium content of the greens, the average decrease being 0.046 percent (table 7). The decrease was, however, significant only at Blairsville, spring of 1940, and at West Point and Sandhill. At Experiment, 1940, Stoneville, 1940, and Iowa Park a significant increase in calcium resulted from the application of phosphorus. The application of potassium produced a significant increase in calcium at Stoneville, 1940, Clemson, 1939, and Sandhill; and a significant decrease at Tifton and at Poplarville, spring of 1939. The interaction effect of NK was significantly negative at Blairsville, 1940, Experiment, 1940, Tifton, West Point, and Edisto. There was also a significant negative interaction effect of NP at Blairsville, 1940, Tifton, Stoneville, 1940, and Heavener. The treatment PK had a significant positive interaction effect at Woodward (irrigated plot) and at Edisto.

The average calcium content of the greens, the effects for 29 experiments combined and for the low- and high-error groups, and the F values from analyses of variance, are given in table 7. The data from Iowa Park were omitted because the fertilizer treatments were not replicated at this place. For the combined data, and for the low-error group, 5 treatments gave significant effects which were the same: N and P gave a highly significant negative effect, and Ca a highly significant positive effect, while NP and NK showed a significant negative interaction effect. There was a significant interaction of treatment $\times$ places for N, P, K, Ca, NP and NK in the 29 experiments and in the low-error group. This shows that the effects of the individual fertilizer treatments varied with the place. In the high-error group, N gave a highly significant negative effect and a significant interaction treatment $\times$ places as in the other 2 groups. There was also a significant negative interaction effect for PCa.

The F values in the analyses of variance were determined both on the basis of error variance and on the basis of interaction variance

TABLE 6.—*Significant effects of the 16 fertilizer treatments on calcium content of turnip greens from the 30 experiments*

Experiment No.	Location	Average effect of fertilizer treatments on the percentage of calcium															Odds of—	
		NPKCa	NPK	NPCa	NP	NKCa	NK	NCa	N	PKCa	PK	PCa	P	KCa	K	Ca	19:1	99:1
	Georgia:																	
1	Blairsville								−1.712**								1.318	0.439
2	do				−0.211**		−0.256**		−.183*				−0.404**				.141	.195
3	Experiment								−.626**								.295	.408
4	do		+0.091*				−.081*		−.155**	+0.086*			+.081*				.074	.102
5	Tifton			−.202*			−.314**								−0.383**		.150	.208
	Mississippi:																	
6	Crystal Springs								−.407**								.108	.150
7	do								−1.079**								.149	.206
8	Natchez								−.558**								.234	.323
9	Poplarville								−.344**						−.260*	+0.233*	.246	.341
10	do								−.258**								.095	.131
11	do								−.400**								.157	.217
12	Stoneville																.202	.279
13	do			−0.152**	−.122**			−0.132**	−.767**				+.097*		+.184**		.085	.118
14	West Point						−.194**		−.373**				−.380**				.136	.185
	Oklahoma:																	
15	Heavener				−.140**				−.395**								.088	.123
16	Perkins											−0.350*					.261	.361
17	do								−.203**								.121	.167
18	Woodward								−.525**								.145	.201
19	do								−.206**								.128	.177
20	do								−.376**		+0.114*						.103	.143
	South Carolina:																	
21	Clemson								−.142*						+.162**		.111	.153
22	Edisto						−.181*			+.175*	+.138*					+.195**	.137	.189
23	Sandhill	+0.161*	−.168*						−.247**				−.226**		+.248**		.154	.213
	Texas:																	
24	College Station								−.305**								.111	.154
25	Iowa Park												+.285*				.238	.370
26	Winter Haven								−.183**							+.121*	.115	.159
27	do								−.224*								.173	.239
	Virginia:																	
28	Blacksburg								−221*							+.450**	.181	.250
29	Norfolk								−.349**								.320	.443
30	do																.107	.147

*=Significant at odds of 19:1; **=significant at odds of 99:1.

(*14*). The effects of each of the variables, place, treatment, and replication, were highly significant for the low- and high-error groups, as well as for the combined experiments. Place (experiment) had much the greatest effect, as shown by the *F* values. These values were 12 to 13 times greater for place than for treatment in the low-error group. Replications had the smallest effect. There was a highly significant interaction between place and treatment in both the low- and high-error groups and for the 29 experiments combined.

TABLE 7.—*Results of 29 experiments combined and of those in the low- and high-error groups, showing the average calcium content of turnip greens, the average effects of the fertilizer treatments, and the F values from the variance analysis of each group—*

Fertilizer treatment	Total group (29 experiments [1])		Low-error group (22 experiments [2])		High-error group (7 experiments [3])	
	Average Ca content, 58 plots (dry basis)	Average effect of treatment, 464 plots	Average Ca content, 44 plots (dry basis)	Average effect of treatment, 352 plots	Average Ca content, 14 plots (dry basis)	Average effect of treatment, 112 plots
	Percent		*Percent*		*Percent*	
NPKCa	2.552	+0.010	2.619	+0.010	2.342	+0.011
NPK	2.482	−.012	2.516	−.008	2.374	−.024
NPCa	2.576	−.003	2.642	−.006	2.368	+.007
NP	2.589	−.037*	2.627	−.030*†	2.471	−.059
NKCa	2.649	−.012	2.671	−.007	2.582	−.031
NK	2.582	−.044**†	2.647	−.062**††	2.377	+.013
NCa	2.700	−.004	2.750	−.003	2.545	−.004
N	2.600	−.363**††	2.662	−.309**††	2.406	−.532**††
PKCa	3.016	+.019	3.033	+.027	2.961	−.009
PK	2.929	−.004	2.919	−.002	2.958	−.009
PCa	2.924	+.025	2.924	+.008	2.925	−.127*
P	2.929	−.046**††	2.882	−.051**††	3.075	−.030
KCa	3.031	−.025	3.018	+.012	3.071	+.065
K	2.916	−.006††	2.965	+.005††	2.760	−.042
Ca	2.972	+.060**††	2.956	+.061**††	3.024	+.057
Check	2.916		2.907		2.945	
Mean	2.773		2.796		2.699	
Standard deviation	.229		.167		.360	
Odds at 19:1	.091	.032	.076	.027	.291	.103
Odds at 99:1	.124	.044	.105	.037	.402	.142
Treatment *F* values:						
Residual as error	41.97**		45.18**		9.06**	
Place × treatment as error	17.10**		15.28**		4.29**	
Place *F* values:						
Residual as error	250.09**		586.26**		28.27**	
Place × treatment as error	101.89**		198.25**		13.39**	
Replication *F* value:						
Residual as error	2.19**		1.92**		2.37*	

[1] Iowa Park is omitted from the variance analyses.
[2] Factorial experiment Nos. 2, 4, 5, 6, 7, 10, 11, 13, 14, 15, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 30.
[3] Factorial experiment Nos. 1, 3, 8, 9, 12, 16, 29.
†=significant interaction of treatment × places at odds of 19:1; ††=significant interaction of treatment × places at odds of 99:1.
*=Significant at odds of 19:1; **=significant at odds of 99:1. †=significant interaction of treatment × places at odds of 19:1; ††=significant interaction of treatment × places at odds of 99:1.

THE EFFECTS OF FERTILIZER TREATMENT AS RELATED TO LEVEL OF SOIL CALCIUM

It seemed probable that the calcium content of the turnip greens was influenced not only by the fertilizer treatments, but also by the interrelated effect of the treatments and the soil calcium. The effects of the fertilizer treatments at different levels of soil calcium were, therefore, studied. The soils were classified as trace-, low-, medium-, and high-calcium soils (table 2) and the effects of the fertilizer treatments determined for each class in the 28 experiments from which

soil samples were analyzed, and in the 22 experiments of the low-error group. The results for the low-error group and the *F* values for the analyses of variance are shown in table 8. There was a significant increase in the calcium content of the greens when calcium was added to the soil in the trace group, and a small but significant increase when it was added to the soil in the low- and high-calcium groups. The greatest effect for calcium treatment was shown in the trace-calcium

TABLE 8.—*Results of the experiments from the low-error group, showing the calcium content of turnip greens grown on trace-, low-, medium-, and high-calcium soils, the average effect of the fertilizer treatments, and the F values from the variance analysis of each group*

Fertilizer treatment	Trace-calcium soils (5 experiments [1])		Low-calcium soils (4 experiments [2])		Medium-calcium soils (3 experiments [3])		High-calcium soils (10 experiments [4])	
	Average Ca content, 10 plots (dry basis)	Average effect of treatment, 80 plots	Average Ca content, 8 plots (dry basis)	Average effect of treatment, 64 plots	Average Ca content, 6 plots (dry basis)	Average effect of treatment, 48 plots	Average Ca content, 20 plots (dry basis)	Average effect of treatment, 160 plots
	Percent		*Percent*		*Percent*		*Percent*	
NPKCa	2.167	+0.025	2.234	−0.003	2.742	−0.006	2.962	+0.013
NPK	1.997	−.069*	2.099	+.037	2.821	+.029	2.851	−.007
NPCa	2.353	+.027	2.148	−.033	2.840	−.011	2.926	−.014
NP	2.245	−.032	2.150	−.002	2.889	−.089**	2.930	−.022
NKCa	2.305	−.028	2.138	−.025	2.801	+.025	3.028	+.002
NK	2.221	−.103**†	2.145	−.064*	2.924	−.011	2.976	−.056**††
NCa	2.418	+.009	2.271	+.004	2.862	−.029	3.073	−.005
N	2.205	−.219**††	2.150	−.441**††	2.936	−.301**†	3.013	−.304**††
PKCa	2.559	+.023	2.750	+.069*	3.136	+.010	3.353	+.018
PK	2.452	−.015	2.524	+.007	3.174	−.052	3.235	+.017
PCa	2.392	−.031	2.554	+.027	3.309	+.028	3.223	+.013
P	2.363	−.065*	2.575	−.016	3.238	+.032	3.158	−.084**††
KCa	2.596	+.012	2.673	+.027	3.040	−.045	3.360	+.025
K	2.371	−.030†	2.690	+.038	3.188	−.049	3.305	+.025††
Ca	2.536	+.135**††	2.560	+.057*††	3.084	−.052	3.285	+.059**
Check	2.393		2.536		3.058		3.267	
Mean	2.348		2.387		3.003		3.122	
Standard deviation	.199		.160		.143		.164	
Odds 19:1	.178	.063	.158	.056	.167	.059	.102	.036
Odds 99:1	.235	.083	.212	.075	.221	.078	.136	.048
Treatment *F* values:								
Residual as error	6.19**		20.14**		8.81**		216.28**	
Place×treatment as error	2.26*		3.32*		7.85**		8.05**	
Place *F* values:								
Residual as error	273.14**		189.38**		383.36**		747.00**	
Place×treatment as error	99.72**		35.40**		343.00**		278.05**	
Replication *F* value:								
Residual as error			1.05				2.60**	

[1] Factorial experiment Nos. 5, 10, 11, 23, 28.
[2] Factorial experiment Nos. 4, 6, 7, 22.
[3] Factorial experiment Nos. 15, 17, 24.
[4] Factorial experiment Nos. 2, 13, 14, 18, 19, 20, 21, 26, 27, 30.
*=Significant at odds of 19: 1; **=significant at odds of 99: 1; †=significant interaction of treatment × places at odds of 19: 1; ††=significant interaction of treatment×places at odds of 99:1.

soils. The medium group did not show any effect from applied calcium, but this may have been due to an insufficient number of experiments. The average percentage of calcium in the greens increased as the calcium content of the soil increased, the average for the greens grown on the high-calcium soils being 33 percent greater than that for the greens grown on the trace-calcium soils. Nitrogen significantly decreased the calcium content of the greens in all groups.

Phosphorus also had a negative effect in the trace- and high-calcium soils. NK showed a significant negative interaction effect in the trace-, low-, and high-calcium soils, and NP in the medium-calcium soils.

The effect of the treatments on the different soils within a group was not uniform as is shown by the interaction between treatment and places. There was a significant interaction, treatment x places, for N in all groups; for Ca in the trace- and low-calcium soils; for P in the high-calcium soils; and for K in the trace- and high-calcium soils.

The results both for the average percentage calcium and for effects were essentially the same for the total of 28 experiments[7] as for the 22 experiments in the low-error group (table 8). There was, however, a highly significant interaction between treatment and places for NP in the high-calcium soils of the total experiments.

In the variance analyses of the low-error experiments, the *F* values for treatment determined on the basis of treatments × places interaction, variance increased as the calcium content of the soil increased. These values in the trace-, low-, medium-, and high-calcium soils were 2.26, 3.32, 7.85, and 8.05, respectively. In the low-, medium-, and high-calcium soils of the 28 experiments,[7] the *F* values followed the same trend.

Effect of the Level of Organic Matter in the Soil

The effect of the level of organic matter in the soil on the calcium content of turnip greens was also studied in connection with the fertilizer treatments. The results of 21 experiments in the low-error group and the *F* value for analyses of variance are shown in table 9. The soils were divided, according to the amount of organic matter present, into three groups which for convenience will be referred to as a low, medium, and high group, containing 0.48 to 1.20, 1.20 to 2.00, and 2.00 to 4.00 percent organic matter, respectively. The division was based upon the fact that the soils fell naturally into these three groups, there being an interval between each group. Experiment 14 (West Point) of the low-error group, was eliminated because it introduced heterogeneity into the organic-matter grouping. This soil contained almost three times as much exchangeable calcium as that of any other soil. Correlation studies showed that exchangeable calcium in the soil had a greater influence on the calcium content of the greens than did organic matter.

It will be seen from table 9 that the mean calcium in the greens increased with an increase in organic matter. Applied calcium significantly increased the calcium content of the greens in the medium and high organic-matter groups, but the effect was greater in the group containing the most organic matter. Nitrogen significantly decreased the calcium in all three organic-matter groups.

Since it seemed possible that the results secured for the effect of organic matter might depend upon the level of soil calcium, the soils were subdivided into a high- and a low-calcium group and similarly studied in order to compare the main effects with those shown in table 9. The most important results were those for the mean calcium in the

[7] Table not shown, but is available at the Mississippi Experiment Station.

greens and the effects of applied calcium and nitrogen. In the high- and low-calcium soils there was also an increase in the mean calcium in the greens with increased organic matter. The effects of applied calcium and nitrogen correspond to those shown in table 9, but the effect of nitrogen was greater in the high- than in the low-calcium soils.

TABLE 9.—*Results of the experiments from the low-error group, showing the calcium content of turnip greens grown on soils containing different percentages of organic matter, the average effect of each fertilizer treatment, and the F values from the variance analysis of each group*

Fertilizer treatment	Soils containing 0.48 to 1.20 percent organic matter (7 experiments [1])		Soils containing 1.20 to 2.00 percent organic matter (11 experiments [2])		Soils containing 2.00 to 4.00 percent organic matter (3 experiments [3])	
	Average Ca content, 14 plots (dry basis)	Average effect of treatment, 112 plots	Average Ca content, 22 plots (dry basis)	Average effect of treatment, 176 plots	Average Ca content, 6 plots (dry basis)	Average effect of treatment, 48 plots
	Percent		*Percent*		*Percent*	
NPKCa	2.334	+0.009	2.550	+0.010	2.825	+0.016
NPK	2.303	−.013	2.486	+.006	2.502	−.026
NPCa	2.280	+.013	2.565	−.035*	3.025	+.034
NP	2.302	−.009	2.604	−.040*	2.743	−.053†
NKCa	2.335	−.002	2.598	−.002	2.972	−.039
NK	2.386	−.034	2.533	−.061**††	2.887	−.088**††
NCa	2.282	−.012	2.681	−.010	3.282	+.059
N	2.329	−.282**††	2.582	−.363**††	2.880	−.154**
PKCa	2.665	+.005	3.044	+.024	3.077	+.074
PK	2.648	−.001	2.906	−.006	2.892	−.008
PCa	2.529	+.014	2.967	−.000	3.002	−.004
P	2.540	−.020†	2.899	−.007	2.952	−.178**††
KCa	2.665	+.014	2.975	+.019	3.163	−.030
K	2.644	+.075**††	2.936	−.006††	3.018	−.099*
Ca	2.549	−.010	2.901	+.058**†	3.242	+.214**††
Check	2.566		2.874		2.998	
Mean	2.460		2.756		2.966	
Standard deviation	.172		.159		.193	
Odds at 19:1	.130	.046	.093	.033	.223	.079
Odds at 99:1	.170	.060	.124	.044	.300	.106
Treatment *F* values:						
Residual as error	11.06**		33.13**		5.79**	
Place × treatment as error	7.51**		8.55**		2.55*	
Place *F* values:						
Residual as error	441.02**		269.43**		46.80**	
Place × treatment as error	299.41**		69.49**		20.64**	
Replication *F* values:						
Residual as error	.69		2.04*		2.47	

[1] Factorial experiment Nos. 10, 11, 15, 21, 23, 24, 27.
[2] Factorial experiment Nos. 4, 5, 6, 7, 13, 17, 18, 19, 20, 22, 26.
[3] Factorial experiment Nos. 2, 28, 30.
*= Significant at odds of 19 : 1; **= significant at odds of 99 : 1; †= significant interaction of treatment × places at odds of 19 : 1; ††= significant interaction of treatment × places at odds of 99 : 1.

Other significant effects shown in table 9 are those for K, P, NP, and NK. Potassium increased the calcium content of the greens in the low organic-matter soils, but decreased it in the high organic-matter soils. The effect of phosphorus was to decrease the calcium in the high organic-matter group. NP and NK produced a significant negative interaction effect in the medium organic-matter group, and NK in the high group as well. In the majority of instances, there was a significant interaction between treatment and places for those treatments which showed significant effects. Exceptions to this were K in the medium, and P in the low organic-matter soils where there were interactions of treatment × places, but no significant effects.

When the 28 experiments [7] were studied with respect to organic matter as were those in the low-error group, the effects and interactions of treatment × places were similar. K, however, failed to show a significant effect in any group, whereas P gave a significant negative effect in the medium as well as in the high organic-matter group. PCa had a significant negative interaction effect, and KCa a significant positive effect in the medium organic-matter soils.

The *F* values from analyses of variance showed that there was a highly significant variation for both place and treatment. The variation due to place decreased with increased organic matter. The above was true for both the low-error group and the 28 experiments.

Correlation Coefficients and Regression Equations

By means of correlation coefficients and regression equations, it was possible to study the relation between the calcium content of the greens and a number of soil properties. These included the available soil calcium as determined by the rapid soil test, exchangeable calcium total exchange capacity, percent organic matter, and soil pH. Ex-

Table 10.—*Correlation coefficients and regression equations showing relations between exchangeable calcium and percentage of organic matter, and the calcium in the greens, for the mean and for plots showing significant places × treatment interactions*

Plot	*r*		*R* (exchangeable calcium and organic matter)	Regression equations [1]	Standard error of estimate
	Exchangeable calcium	Organic matter			
NP	0.4696*	0.0098	0.4729**	$2.0995+0.1086x+0.0343x_1$	0.3976
NK	.5277**	.2115	.5523**	$1.9708+.1131x+.0938x_1$	.4307
N	.4461*	.1926	.4712**	$2.0092+.1043x+.0955x_1$	.4997
P	.4667*	.3399	.5535**	$2.1596+.1099x+.1945x_1$	.3918
K	.4477*	.3253	.5306**	$2.2304+.0970x+.1712x_1$	.4572
Ca	.4034*	.3478	.5097**	$2.2993+.0835x+.1813x_1$	.4494
Mean of 16 replicated treatments in each locality	.5257**	.2861	.5771**	$2.1237+.1064x+.1313x_1$	.4041

[1] x=Exchangeable calcium; x_1=organic matter.
*=Significant at odds of 19:1; **=significant at odds of 99:1.

changeable calcium gave the best basis for prediction, and percent organic matter was less related to it than were the other properties. Accordingly, correlation coefficients and regression equations were determined for exchangeable calcium and organic matter in the NP, NK, N, PK, and Ca plots, and for the mean of the experiments, omitting West Point. These plots were studied because the effects of treatment varied greatly at different places and could not be described satisfactorily by the mean regression. The results are given in table 10. The simple correlation coefficients showed a significant positive relation between the calcium in the greens and exchangeable calcium, and a positive relation which was not significant between the calcium in the greens and organic matter. The multiple correlation coefficients for exchangeable calcium and organic matter show a somewhat closer relation than the simple correlation coefficients.

Since the rapid soil test for available calcium, although not quantita-

[7] Table now shown, but is available at the Mississippi Experiment Station.

tive, has the advantage of speed and simplicity, it seemed worthwhile to determine the relation between the calcium in the greens and the level of available soil calcium. The plots studied were the check plots and those to which nitrogen and phosphorus had been added, as the majority of soils were low in these constituents. The correlation coefficients and regression equations are given in table 11. The correlation coefficients show that there was a significant relation between the available soil calcium and that of the greens. The standard error of estimate indicates that the regression equation for the NPK plots is a fairly accurate means for predicting the calcium content of the plant when the rapid soil test for available calcium is used.

TABLE 11.—*Correlation coefficients and regression equations showing relations between available soil calcium and the calcium in the greens on check and fertilized plots*

Plot	*r* (available soil calcium)	Regression equation[1]	Standard error of estimate
NPKCa	0.5354**	1.8771+0.0954X	0.5640
NPK	.5702**	1.7282+ .1048X	.3829
NPCa	.4419*	1.9645+ .0859X	.6531
NP	.4894**	1.9494+ .0900X	.6006
Check	.5300**	2.0352+ .0888X	.6407

[1] X-available soil calcium. Levels of available soil calcium ranging from T- to H+ (table 2) were arbitrarily assigned values from 1 through 12.

COVARIANCE ANALYSES

Covariance analyses were made on the data secured from the 9 places in which crops were grown in 2 successive years. When the means for the calcium content of the greens were adjusted on the basis of soil calcium, as determined by rapid soil tests, the significance of the variation due to place was not eliminated, but when this was done for exchangeable calcium the variation due to place was eliminated.[7] The unadjusted *F* value for the 9 places was small in comparison with the corresponding *F* value for the 28 experiments. Hence, itseemed likely that the number of cases was insufficient.

The covariance analyses, using the 2 series instead of successive crops, were, therefore, worked out for the check and NPK plots in the 28 experiments. It was thought that the calcium in the greens from the check plots would reflect the effects of the soil since no fertilizer was added. The NPK plots, however (to which no calcium was applied), would produce more normal growth. Table 12 shows the relation of the multiple variates, organic matter and exchangable calcium, to the variation in the calcium content of the greens which was attributed to place. Only the maximum possibility for the effects of the soil properties on the variation due to place could be studied since there was but one soil analysis for both series. The *F* value for place in the 28 experiments was 15.91**. This value was reduced to 6.06** when the means were adjusted to eliminate the effect of exchangeable calcium. Since the exchangeable calcium of the West Point soil was so much greater than that of any other soil, an analysis of 27 experiments, excluding West Point, was made.[7] The

[7] Table not shown, but is available at the Mississippi Experiment Station.

TABLE 12.—*Covariance analyses of the average calcium content of turnip greens from the check and NPK plots, showing the effect of exchangeable calcium and organic matter in variation due to place*

Plot	Source of variation	Variance of calcium content of greens (y)				Error of estimate based on exchangeable calcium (x)				Error of extimate based on exchangeable calcium and percent of organic matter				
		Degrees of freedom	Sy^2	Mean square	F	Degrees of freedom	$Sy^2-\frac{(Sxy)^2}{Sx^2}$	Mean square	F	Degrees of freedom	P^2	$(1-P^2)Sy^2$	Mean square	F
Check	Total	55	28.8646			54	12.4683			53	0.6458	10.2239		
	Place	27	27.0992	1.0037	15.91**									
	Error	28	1.7654	.0631		27	1.7654	.0654		26	0	1.7654	0.0679	
	Difference for testing adjusted means					27	10.7029	.3964	6.06**	27		8.4585	.3133	4.61**
NPK	Total	53	14.2900			52	10.4763			51	.5420	6.5448		
	Place	26	13.2451	.5094	13.16**									
	Error	27	1.0449	.0387		26	1.0449	.0402		25	0	1.0449	.0418	
	Difference for testing adjusted means					26	9.4314	.3627	9.02**	26		5.4999	.2115	5.06**

**=Significant at odds of 99 : 1.

F value for place was 8.64**, as compared to 15.91**, indicating that a large portion of the variation attributed to place was accounted for by conditions associated with the West Point experiment. The *F* value for the adjusted means, however, was 5.97**—a value almost identical with the *F* value for the adjusted means of the 28 experiments. The *F* value for place in the 27 experiments was 4.61** when the effects of exchangeable calcium and organic matter were eliminated. For the 22 experiments in the low-error group, the *F* value for place was 20.05**.[7] This was reduced to 4.94** when the means were adjusted on the basis of exchangeable calcium and organic matter. Correlation coefficients indicated that the hydrogen-ion concentration of the soil did not have as important an effect on the calcium in the greens as did exchangeable calcium. This result was verified when the relation of hydrogen-ion concentration to variation in the plant calcium due to place was determined for the check plots. Elimination of the effect of hydrogen-ion concentration reduced the *F* value for place in the 28 experiments from 15.91** to 11.64** while elimination of the effect of exchangeable calcium reduced it to 6.06**.

In the NPK plots, the *F* value for place was 13.16** for 27 experiments. Adjusting the mean values for the calcium content of the turnip greens on the basis of exchangeable calcium reduced this *F* value to 9.02**. It is evident from the data presented that the variation in soil composition affects the calcium content of the greens, but that no one factor, or any of the combinations studied, accounts for all the significant differences associated with the individual places.

PHOSPHORUS

The data on phosphorus were studied in a manner similar to that for calcium. Table 13 shows the average phosphorus in the turnip greens grown in duplicate plots, the mean for each experiment, and the standard deviation. The mean percentage of phosphorus in the greens from the 30 experiments ranged from 0.3531 at West Point to 0.7203 at Stoneville. Table 14 shows the significant effects of the fertilizer treatments. It will be seen that each of the fertilizer treatments had a significant effect in one or more experiments. There were four experiments, however, in which there was no significant effect for any treatment. The experiments were those at Experiment, spring of 1939, Winter Haven, fall of 1939 and 1940, and Norfolk, fall of 1939.

*Significant at odds of 19:1; **significant at odds of 99:1.
[7] Table not shown, but is available at the Mississippi Experiment Station.

TABLE 13.—*Phosphorus content of turnip greens grown by a factorial design of 16 duplicate fertilizer treatments in 30 experiments*

Experiment No.	Location	Year	Average content of phosphorus (dry basis) of greens from duplicate plots fertilized with—																Mean	Standard deviation	Odds of—	
			NPKCa	NPK	NPCa	NP	NKCa	NK	NCa	N	PKCa	PK	PCa	P	KCa	K	Ca	Check			19:1	99:1
	Georgia:		*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*			
1	Blairsville	1939	0.7090	0.8045	0.8450	0.7080	0.6000	0.5365	0.6305	0.5830	0.6235	0.5160	0.5855	0.5500	0.4270	0.5380	0.5265	0.4330	0.6010	0.0765	0.1632	0.2257
2	....do	1940	.6190	.5745	.5505	.5720	.4150	.4370	.4435	.4275	.6445	.6105	.6290	.6550	.5635	.5150	.5405	.5845	.5488	.0554	.1182	.1635
3	Experiment	1939	.5860	.5270	.5790	.5890	.5550	.5510	.5090	.5475	.5680	.5655	.5695	.5680	.5840	.5785	.5590	.6090	.5653	.0385	.0820	.1134
4	....do	1940 [1]	.4460	.4650	.4905	.4570	.4190	.4445	.4190	.3890	.4920	.4585	.4760	.4315	.4485	.4080	.3950	.4015	.4401	.0304	.0648	.0899
5	Tifton	1939	.4850	.6610	.7265	.5935	.5105	.5685	.5800	.5300	.5185	.5780	.5895	.5980	.5135	.5865	.5030	.5530	.5684	.0517	.1100	.1525
	Mississippi:																					
6	Crystal Springs	1939 [1]	.7850	.6600	.7550	.7950	.7500	.7450	.7400	.7550	.6050	.5900	.5900	.5750	.5950	.5700	.5750	.5750	.6663	.0246	.0523	.0724
7	....do	1940	.5050	.4550	.5250	.4350	.5000	.4200	.4250	.3550	.5950	.5200	.6650	.6150	.5850	.6000	.5400	.5850	.5203	.0506	.1078	.1485
8	Natchez	1939	.5900	.6050	.6550	.6450	.5400	.5250	.5950	.5500	.5650	.5650	.5550	.4850	.4950	.5800	.5450	.6400	.5709	.0475	.1013	.1400
9	Poplarville	1939	.4600	.5000	.5650	.5050	.4150	.3800	.3800	.4150	.5750	.5750	.5750	.6300	.5450	.5050	.3200	.5250	.4919	.0784	.1672	.2311
10	....do	1939 [1]	.4500	.4600	.4350	.4650	.3900	.4000	.4100	.4100	.4150	.4500	.4250	.4400	.3750	.3900	.3700	.4150	.4188	.0232	.0495	.0684
11	....do	1940	.5350	.5850	.6250	.5500	.4400	.4450	.4400	.4850	.6000	.6050	.5800	.6350	.5550	.6150	.5950	.6200	.5569	.0332	.0707	.0973
12	Stoneville	1939 [1]	.6750	.6850	.7150	.7900	.6550	.7150	.7150	.7200	.7600	.7250	.7000	.6750	.7750	.7550	.7500	.7450	.7203	.0347	.0738	.1024
13	....do	1940	.7150	.7000	.7600	.7700	.7000	.7000	.7200	.6900	.6450	.7000	.6650	.7050	.6750	.6600	.6750	.6750	.6972	.0316	.0673	.0936
14	West Point	1939	.3700	.3350	.3800	.3500	.3650	.3650	.3900	.3900	.3350	.3500	.3100	.3050	.3450	.3600	.3450	.3550	.3531	.0167	.0354	.0492
	Oklahoma:																					
15	Heavener	1939	.7105	.6425	.6380	.6665	.4940	.5070	.5495	.5610	.7110	.7025	.7080	.7150	.6440	.5725	.6125	.6300	.6290	.0372	.0795	.1097
16	Perkins	1939	.4915	.5545	.5290	.5465	.4830	.4280	.4805	.4555	.5953	.5605	.5595	.5495	.5330	.4680	.5230	.4950	.5158	.0384	.0817	.1131
17	....do	1940	.5405	.4370	.4860	.5215	.4775	.3435	.4325	.4335	.6125	.5675	.5960	.5290	.4495	.4535	.4970	.4065	.4865	.0570	.1213	.1680
18	Woodward	1939	.5190	.5155	.4700	.4990	.3800	.4090	.3970	.4025	.5280	.5495	.4965	.5540	.4360	.4265	.4210	.4065	.4631	.0295	.0634	.0880
19	....do	1939 [1]	.5835	.5760	.5950	.6135	.5005	.5130	.5120	.5005	.5415	.6020	.5725	.5575	.5445	.5320	.5165	.5255	.5491	.0317	.0676	.0933
20	....do [2]	1940	.6145	.6845	.6090	.6815	.5830	.5485	.5150	.5520	.5965	.6000	.5875	.6730	.5920	.5765	.6795	.5990	.6058	.0321	.0684	.0945
	South Carolina:																					
21	Clemson	1939 [1]	.4635	.5495	.5430	.5365	.5290	.4790	.5325	.4895	.5470	.4885	.5470	.5585	.5445	.5270	.5275	.5635	.5266	.0261	.0557	.0769
22	Edisto	1939 [1]	.5585	.6050	.5865	.5815	.5590	.5250	.5700	.5110	.6570	.6175	.6415	.5980	.6240	.6040	.6350	.5995	.5921	.0269	.0577	.0795
23	Sandhill	1940	.5720	.6565	.5885	.5595	.4935	.4935	.5625	.5800	.5260	.4965	.5965	.6200	.5380	.5745	.5115	.4680	.5523	.0412	.0880	.1213
	Texas:																					
24	College Station	1940 [1]	.7055	.7400	.8230	.8010	.7190	.6515	.6825	.7745	.6630	.7015	.6490	.6550	.6745	.7295	.6970	.6000	.7042	.0573	.1222	.1689
25	Iowa Park [3]	1939 [1]	.390	.355	.378	.381	.401	.334	.321	.436	.380	.388	.386	.437	.493	.447	.413	.427	.3979	.0437	.1318	.1821
26	Winter Haven	1939 [1]	.6960	.6290	.6265	.6740	.6595	.6240	.6470	.6040	.6895	.6780	.6710	.7015	.6375	.6685	.6685	.6505	.6578	.0356	.0758	.1049
27	....do	1940 [1]	.6560	.6470	.6760	.6395	[4] .6695	.6290	.6165	.6435	.6745	.6165	.6775	.6600	.6570	.6575	.6530	.6015	.6484	.0385	.0820	.1134
	Virginia:																					
28	Blacksburg	1940	.6575	.6135	.7555	.6735	.5280	.5130	.5295	.4560	.7430	.6200	.6900	.7030	.5700	.5850	.5735	.5295	.6069	.0751	.1598	.2215
29	Norfolk	1939 [1]	.5500	.4650	.6600	.6200	.4800	.5900	.5300	.4850	.4700	.5700	.5700	.4750	.5250	.4500	.4000	.4200	.5163	.1057	.2251	.3114
30	....do	1940 [1]	.5955	.5875	.4815	.5495	.4675	.4820	.4590	.4590	.5825	.5065	.5415	.5680	.5305	.5380	.5090	.3745	.5145	.0468	.0998	.1380

[1] Fall crops. Undesignated crops were grown in the spring.
[2] Plots were irrigated.
[3] Iowa Park plots were not replicated; hence, the Mean is an average of 16 plots.
[4] Calculated result for 1 missing plot.

TABLE 14.—*Significant effects of the 16 fertilizer treatments on the phosphorus content of turnip greens from 30 experiments*

Experiment No.	Location	Average effect of indicated fertilizer treatment on the percentage of phosphorus							
		NPKCa	NPK	NPCa	NP	NKCa	NK	NCa	N
	Georgia:								
1	Blairsville	−0.0660*							+0.1525**
2	——do								−.0879**
3	Experiment								
4	——do								
5	Tifton					−0.0499*			
	Mississippi:								
6	Crystal Springs	+.0213*				+.0200*	−0.0188*		+.1638*
7	——do								−.1356**
8	Natchez			−0.0419*	+0.0469*				
9	Poplarville								−.0788*
10	——do								+.0175*
11	——do	−.0313*			+.0563**				−.0875**
12	Stoneville						−.0406**		−.0306*
13	——do								+.0444**
14	West Point						−.0188**	+0.0125*	+.0300**
	Oklahoma:								
15	Heavener								−.0658**
16	Perkins								−.0394*
17	——do					+.0488*			−.0549*
18	Woodward								−.0283*
19	——do								
20	——do	−.0270*			+.0476**		+.0309*		
	South Carolina:								
21	Clemson			−.0298**		−.0261*			−.0126*
22	Edisto								−.0600**
23	Sandhill	−.0330*	+0.0704**						
	Texas:								
24	College Station						−.0541*		+.0659**
25	Iowa Park								−.0469*
26	Winter Haven								
27	——do								
	Virginia:								
28	Blacksburg								
29	Norfolk								
30	——do		+.0408*						

TABLE 14.—*Significant effects of the 16 fertilizer treatments on the phosphorus content of turnip greens from 30 experiments*—Continued

Experiment No.	Location	Average effect of indicated fertilizer treatment on the percentage of phosphorus							Odds of—	
		PKCa	PK	PCa	P	KCa	K	Ca	19:1	99:1
	Georgia:									
1	Blairsville				+0.1338**				0.0577	0.0798
2	——do				+.1161**				.0418	.0578
3	Experiment								.0290	.0401
4	——do				+.0490**				.0229	.0318
5	Tifton				+.0506*	−.0614**			.0389	.0539
	Mississippi:									
6	Crystal Springs								.0185	.0256
7	——do		−0.0456*		+.0381*			+0.0444*	.0381	.0525
8	Natchez								.0358	.0495
9	Poplarville				+.1125**				.0591	.0817
10	——do				+.0475**			−.0200*	.0175	.0242
11	——do				+.0650**				.0250	.0344
12	Stoneville								.0261	.0362
13	——do								.0238	.0331
14	West Point				−.0225**				.0125	.0174
	Oklahoma:									
15	Heavener				+.1154**				.0281	.0388
16	Perkins				+.0651**				.0289	.0400
17	——do				+.0996**			+.0500*	.0429	.0594
18	Woodward				+.1066**				.0224	.0311
19	——do				+.0621**				.0239	.0330
20	——do			−0.0406**	+.0501**				.0242	.0334
	South Carolina:									
21	Clemson						−0.0213*		.0197	.0272
22	Edisto				+.0273*			+.0238*	.0204	.0281
23	Sandhill				+.0493**				.0311	.0429
	Texas:									
24	College Station								.0432	.0597
25	Iowa Park								.0466	.0644
26	Winter Haven								.0268	.0371
27	——do								.0290	.0401
	Virginia:									
28	Blacksburg				+.1427**				.0565	.0783
29	Norfolk								.0796	.1101
30	——do	+0.0419*			+.0741**		+.0435*		.0353	.0488

*Significant at odds of 19:1; **significant at odds of 99:1.

The most outstanding effect of the fertilizer treatments was that of phosphorus. It increased the phosphorus content of the greens significantly in 18 experiments. The average increase was 0.0537 percent (table 15). The effect of nitrogen on the phosphorus content of turnip greens was similar to its effect on calcium, although less consistent. Nitrogen decreased the phosphorus significantly in 12 experiments, but had a negative effect in 18 experiments. Six places, however, showed a significant increase; namely, Blairsville, spring of 1939; Crystal Springs, fall of 1939; Poplarville, fall of 1939; Stoneville, spring of 1940; West Point, 1939; and College Station, fall of 1940. Calcium added as fertilizer showed a tendency to increase the phosphorus content of the greens, but this increase was significant at only three places, Crystal Springs 1940, Perkins 1940, and Edisto, and there was a significant decrease in phosphorus at Poplarville, fall of 1939. At Clemson, 1939, the phosphorus content

TABLE 15.—*Results of 29 experiments combined and of those in the low- and high-error groups, showing the average phosphorus content of turnip greens, the average effects of the fertilizer treatments, and the* F *values from the variance analysis of each group*

Fertilizer treatment	Total group (29 experiments [1])		Low-error group (18 experiments [2])		Medium-error group (7 experiments [3])		High-error group (4 experiments [4])	
	Average P content, 58 plots (dry basis)	Average effect of treatment, 464 plots	Average P content, 36 plots (dry basis)	Average effect of treatment, 288 plots	Average P content, 14 plots (dry basis)	Average effect of treatment, 112 plots	Average P content, 8 plots (dry basis)	Average effect of treatment, 64 plots
	Percent		*Percent*		*Percent*		*Percent*	
NPKCa	0.5808	+0.0007††	0.5793	−0.0012	0.5772	+0.0099	0.5941	−0.0070†
NPK	.5834	+.0001	.5821	−.0001††	.5800	+.0029	.5958	−.0040
NPCa	.6094	−.0030	.5889	−.0005	.6068	−.0095	.7064	−.0025
NP	.5986	+.0151**	.5963	+.0135**††	.5882	+.0195*†	.6266	+.0146
NKCa	.5268	−.0026	.5547	−.0015	.5185	+.0041†	.5058	−.0195
NK	.5162	−.0092*	.5290	−.0052	.4896	−.0088†	.5049	−.0282
NCa	.5315	+.0016	.5403	−.0018	.5168	+.0045	.5175	+.0119
N	.5226	−.0059††	.5381	−.0065*††	.5042	−.0228**††	.4848	+.0260††
PKCa	.5889	+.0003	.5826	+.0015	.5973	+.0005	.6029	−.0054
PK	.5754	−.0083*	.5753	−.0022	.5784	−.0092	.5763	−.0338*
PCa	.5858	+.0001	.5763	−.0040	.6036	+.0031	.5976	+.0136
P	.5857	+.0537**††	.5845	+.0377**††	.5864	+.0613**††	.5895	+.1129**
KCa	.5511	−.0003	.5613	+.0035	.5445	−.0054†	.5168	−.0088
K	.5526	−.0045	.5524	−.0045	.5718	−.0038	.5195	−.0055
Ca	.5401	+.0054	.5562	+.0012	.5474	+.0098†	.4550	+.0161
Check	.5373		.5519		.5348		.4761	
Mean	.5616		.5643		.5591		.5540	
Standard deviation	.0504		.0381		.0522		.0844	
Odds at 19:1	.0201	.0071	.0184	.0065	.0421	.0149	.0899	.0318
Odds at 99:1	.0277	.0098	.0263	.0093	.0583	.0206	.1244	.0440
Treatment *F* values:								
Residual as error	20.62**		11.48**		7.14**		5.02**	
Place × treatment as error	9.13**		4.49**		2.59**		3.21**	
Place *F* values:								
Residual as error	95.07**		221.40**		59.10**		15.40**	
Place × treatment as error	42.08**		86.69**		21.44**		9.84**	
Replication *F* values:								
Residual as error	1.78**		0.43		2.50*		2.53*	

[1] Iowa Park is omitted from the variance analyses.
[2] Factorial experiment Nos. 3, 4, 6, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 26, 27.
[3] Factorial experiment Nos. 2, 5, 7, 8, 17, 24, 30.
[4] Factorial experiment Nos. 1, 9, 28, 29.
*=Significant at odds of 19: 1; **=significant at odds of 99: 1; †=significant interaction of treatment × places at odds of 19: 1; †† significant interaction of treatment × places at odds of 99: 1.

of the greens was significantly decreased by potassium, and at Norfolk, 1940, it was significantly increased. There were significant positive interaction effects for NP at Natchez, Poplarville, 1940, and at Woodward, 1940. The treatment NK gave a significant negative interaction effect at Crystal Springs, 1940, Stoneville, 1939, West Point and College Station, and a significant positive effect for the irrigated plot at Woodward.

The results for the 29 experiments combined, for the low-medium- and high-error groups and the *F* values for the analyses of variance are given in table 15. Four treatments gave significant effects for the 29 experiments. Phosphorus showed a highly significant positive effect. NK and PK had a significant negative interaction effect, and NP a highly significant positive interaction effect. There was a significant interaction between places and the treatment of N, P, and of NPKCa in the 29 experiments.

In the low-error group, the effects of the treatments P and NP corresponded to those for the 29 experiments. Nitrogen, however, gave a significant negative effect, whereas NK and PK gave no significant interaction effects. The effects showing significance for the medium-error group were like those for the low-error group. Only two treatments, P and PK, gave a significant effect in the high-error group, P having a highly significant positive effect as in the other groups and in the combined experiments, and PK a negative interaction effect. There was significant treatment × places interactions for the following treatments in the three error groups: NPKCa, NPK, NP, N, and P in the low-error groups; NP, NKCa, NK, N, P, KCa, and Ca in the medium-error group; and NPKCa and N in the high-error group.

In the variance analyses the effects of the three variables, place, treatment, and replication, on the phosphorus content of the greens were similar to those for calcium. Again the effect of place was much greater than that for treatment, although treatment had a highly significant effect. Replications had the smallest effect and this effect was not significant in the low-error group.

Effect of Fertilizer Treatment as Related to Level of Soil Phosphorus

The phosphorus content of the greens was studied in relation to the level of soil phosphorus and fertilizer treatments in the same manner as was the calcium content of the greens in relation to the soil calcium. Table 16 shows the results for the low-error experiments and the *F* values for analyses of variance when the soils were grouped into low-, medium-, and high-phosphorus soils. The majority of the soils on which the turnip greens were grown were, however, low-phosphorus soils. Two of the three experiments having medium-phosphorus soils and both having high-phosphorus soils were in the low-error group. The high-phosphorus soils were in reality the same soil, since the two experiments were conducted at the same place, but in different seasons. The data are, therefore, insufficient in the medium- and high-phosphorus groups to do more than indicate trends.

It will be seen from the table that the mean phosphorus content of the greens increased as the soil phosphorus increased, the phosphorus being highest in the greens grown in soils which contained the most

phosphorus. The low-phosphorus soils gave more significant effects and more interactions than either the medium- or the high-phosphorus soils. There were three significant effects for fertilizer treatments—a positive effect for P, a negative effect for N, and a positive interaction effect for NP. Highly significant treatment × places interactions were given by the treatments NPKCa, NPK, NP, N, and P. In the medium-phosphorus soils N had a highly significant, and Ca a significant, positive effect. There were only two treatment × places interactions, one for NPKCa and one for N. The high-phosphorus soils gave a significant positive interaction effect for NP, and a significant negative interaction effect for NK. There was significant treatment × places interaction for N, but no significant effect, since in one experiment there was a significant negative effect and in the other a highly significant positive effect of about the same order.

In the 28 experiments the low-phosphorus soils included 8 additional experiments (experiments 2, 5, 7, 9, 13, 17, 29, 30), and the medium soils 1 additional experiment (experiment 24). There was also a group for trace-phosphorus soils (experiments 1 and 15). The results were

TABTE 16.—*Results of the experiments from the low-error group, showing the phosphorus content of turnip greens grown on low-, medium-, and high-phosphorus soils, the average effect of the fertilizer treatment, and the F values from the variance analysis of each group*

Fertilizer treatment	Low-P soils (14 experiments [1])		Medium-P soils (2 experiments [2])		High-P soils (2 experiments [3])	
	Average P content, 28 plots (dry basis)	Average effect of treatment, 224 plots	Average P content, 4 plots (dry basis	Average effect of treatment, 32 plots	Average P content, 4 plots (dry basis)	Average effect of treatment, 32 plotes
	Percent		*Percent*		*Percent*	
NPKCa	0.5426	−0.0030††	0.7205	−0.0011††	0.6950	+0.0113
NPK	.5561	+.0024††	.6535	−.0040	.6925	−.0138
NPCa	.5496	−.0020	.7155	+.0061	.7375	+.0038
NP	.5550	+.0150**††	.7173	−.0025	.7650	+.0188*
NKCa	.4893	−.0034	.7098	+.0132	.6775	−.0031
NK	.4809	−.0018	.6870	−.0086	.7075	−.0256**
NCa	.4953	−.0011	.6783	−.0030	.7175	−.0056
N	.4913	−.0208**††	.6993	+.0806**††	.7050	+.0069††
PKCa	.5573	−.0001	.6398	+.0073	.7025	+.0069
PK	.5517	+.0002	.6033	−.0155	.7125	−.0056
PCa	.5529	−.0058†	.6338	+.0098	.6825	−.0056
P	.5648	+.0467**††	.6175	+.0106	.6900	+.0019
KCa	.5286	+.0024	.6260	+.0149	.7250	+.0000
K	.5215	−.0034	.6138	−.0013	.7075	−.0125
Ca	.5256	−.0005	.6140	+.0197*	.7125	−.0050
Check	.5241		.5883		.7100	
Mean	.5304		.6573		.7088	
Standard deviation	.0338		.0316		.0332	
Odds at 19:1	.0178	.0063	.0455	.0161	.0478	.0169
Odds at 99:1	.0235	.0083	.0614	.0217	.0645	.0228
Treatment of *F* values:						
Residual as error	19.13**		8.49**		1.64	
Place × treatment as error	8.25**		.10		.62	
Place *F* values:						
Residual as error	204.95**		5.16*		7.82**	
Place × treatment as error	88.38**		.60		2.97	
Replication *F* value:						
Residual as error	7.29*		1.71		1.09	

[1] Factorial experiment Nos. 3, 4, 10, 11, 14, 15, 16, 18, 19, 20, 21, 22, 23, 26.
[2] Factorial experiment Nos. 6, 27.
[3] Factorial experiment Nos. 12, 13.
*=Significant at odds of 19:1; **=significant at odds of 99:1; †=significant interaction of treatment × places at odds of 19:1; ††=signficant interaction of treatment × places at odds of 99:1.

comparable to those for the low-error experiments except that the effects on low-phosphorus soils in the 28 experiments showed an even greater degree of significance.[7] Six treatments, P, Ca, N, NP, NK, and PK had a highly significant effect. P and Ca had a positive effect and N a negative effect. The interaction effect of NP was positive and that of NK and PK was negative. There was a highly significant treatment × places interaction for each of the 15 treatments.

In none of the other soil groups were there more than three significant effects or interactions of treatment and places. In the trace-phosphorus soils the treatments N and P had a highly significant positive effect and NP a significant positive interaction effect, and there was a significant interaction for N. In the medium-phosphorus soils N had a highly significant positive effect, whereas NK had a highly significant negative interaction effect. Significant treatment × places interaction was shown by NK and a highly significant interaction by N. The high-phosphorus group was identical with that in the low-error experiments.

In the analyses of variance for the low-error experiments (table 16), the *F* values for place on the basis of residual as error in the medium- and high-phosphorus soils were significant, but were very much smaller than the *F* values for place on the low-phosphorus soils. This was true for the 28 experiments [7] as well as for the 18 low-error experiments, but the differences in the *F* values were greater for the 28 experiments. The *F* values for treatment on the basis of residual as error were highly significant for the low- and medium-phosphorus soils of both the low-error and the 28 experiments, but were not significant for the high-phosphorus soils. When the *F* values for treatment were determined on the basis of interaction (place × treatments) as error they were highly significant for the low-phosphorus soils, but not significant for the medium- and high-phosphorus soils of the low-error experiments. The results were the same for the 28 experiments except that the *F* value for the medium-phosphorus soils showed signficance at the 5-percent level.

In order to determine the effect of the level of soil calcium upon the phosphorus content of the greens, the 24 low-phosphorus soils were grouped into low- and high-calcium soils and the effects of the fertilizer treatments studied. Since there were just 5 soils not included in the low-phosphorus group, only the latter could be studied for the effects of soil calcium. It was found that in both the low- and high-calcium soils the effects of the fertilizer treatments were those typical of the low-phosphorus soils in the low-error experiments shown in table 16. The effects for NP, N, and P were greater on the low-calcium soils than on the high-calcium soils. The treatment PCa had a significant negative interaction effect on the high-calcium soils, but not on the low-calcium soils.

In the analyses of variance there was a greater variation due to place on the high- than on the low-calcium soils. There was a greater variation due to treatment, however, on the low-calcium soils.

Effect of the Level of Organic Matter in the Soil

The effect of the level of organic matter on the phosphorus content of the greens was also determined. The soils were classified on the

[7] Table not shown, but is available at the Mississippi Experiment Station.

basis of actual amount of organic matter present. In the low-error experiments there were only two groups of soils—the low group containing 0.48 to 1.20 percent organic matter, and the medium group containing 1.20 to 2.00 percent organic matter—since there was only one soil in the high organic-matter group.

TABLE 17.—*Results of the experiments from the low-error group, showing the average phosphorus content of turnip greens grown on soils containing different percentages of organic matter, the average effect of the fertilizer treatments, and the F values from the variance analysis of each group*

Fertilizer treatment	Soils containing 0.48 to 1.20 percent organic matter (6 experiments [1])		Soils containing 1.20 to 2.00 percent organic matter (11 experiments [2])	
	Average P content, 12 plots (dry basis),	Average effect of treatment, 96 plots	Average Ca content, 22 plots (dry basis)	Average effect of treatment, 176 plots
	Percent		*Percent*	
NPKCa	0.5645	−0.0118*††	0.5867	+0.0035
NPK	.5901	+.0152**†	.5827	−.0072*
NPCa	.5842	−.0029	.5924	+.0006
NP	.5695	+.0171**†	.6116	+.0106**†
NKCa	.5026	−.0070	.5504	+.0008
NK	.4922	−.0012	.5470	−.0078*††
NCa	.5185	−.0006	.5551	−.0032
N	.5281	−.0232**††	.5427	+.0038††
PKCa	.5789	−.0033	.5859	+.0046
PK	.5598	+.0020	.5846	−.0013
PCa	.5890	+.0000	.5700	−.0081*††
P	.6047	+.0495**††	.5750	+.0339**††
KCa	.5522	+.0019	.5641	+.0028
K	.5561	−.0115*	.5481	−.0009
Ca	.5449	−.0019	.5621	+.0034
Check	.5496		.5480	
Mean	.5553		.5691	
Standard deviation	.0336		.0306	
Odds at 19:1	.0272	.0096	.0181	.0064
Odds at 99:1	.0362	.0128	.0246	.0087
Treatment *F* values:				
Residual as error	10.95**		9.54**	
Place × treatment as error	3.46**		2.29**	
Place *F* values:				
Residual as error	190.05**		464.22**	
Place × treatment as error	60.11**		111.26**	
Replication *F* value:				
Residual as error	14.43**		2.20*	

[1] Factorial experiment Nos. 10, 11, 15, 21, 23, 27.
[2] Factorial experiment Nos. 4, 6, 12, 13, 14, 16, 18, 19, 20, 22, 26.
*=Significant at odds of 19:1; **=significant at odds of 99:1; †=significant interaction of treatment × places at odds of 19:1; ††=significant interaction of treatment × places at odds of 99:1.

The results for the low-error experiments are given in table 17. There was a small and not significant increase in the mean phosphorus content of the greens with increased organic matter. In the total of 28 experiments there was a similar trend when the experiments were grouped so that the soil calcium and phosphorus were held at the low level.[7]

The effect of P was to significantly increase the phosphorus content of the greens, and NP had a significant positive interaction effect in the low-error experiments. The same effects were shown when the 28 experiments were grouped into low, medium, and high organic-matter

[7] Table not shown, but is available at the Mississippi Experiment Station.

soils.[7] When the phosphorus and calcium soil levels were held constant, the effect of applied phosphorus seemed to decrease with increased organic matter.

In the low organic-matter group of the low-error experiments, N produced a highly significant decrease in the phosphorus content of the greens, but no significant effect in the medium organic-matter group. This group, however, was made up of 11 experiments, 5 of which (experiments 4, 6, 13, 14, 19) gave a positive effect for nitrogen, highly significant when combined, and 6 of which (experiments 12, 16, 18, 20, 22, 26) gave a negative effect, also highly significant when combined. More of the nitrogen treatments had a significant effect in the low organic-matter group for both low-error and the 28 experiments than for the soil groups having a higher organic-matter content. Potassium showed a tendency to decrease the phosphorus content of the greens, but has a significant effect only in the low organic-matter group of the low-error experiments. The treatment NK gave a significant negative interaction effect in the medium organic-matter group of the low-error experiments, and a similar effect in the low organic-matter group of the total experiments.

All of the first-order treatments in the low-error experiments which give significant effect showed significant interactions for treatment × places except K in the low organic-matter group. In the 28 experiments there were significant interactions for N and P in all 3 organic-matter groups.

In the analyses of variance for the low-error experiments there was an increase in the *F* values for place when the organic matter increased. The variation due to treatment decreased, however, with an increase in organic matter.

Correlation Coefficients and Regression Equations

Correlation studies were made to bring out relations between soil properties and the phosphorus content of the greens. The plots showing significant places × treatment interaction and the mean for all plots were studied as in the case of calcium. The correlation coefficients and regression equations (table 18) show that the phos-

Table 18.—*Correlation coefficients and regression equations showing relations between exchangeable calcium and soil phosphorus, and the phosphorus in the greens for the mean and for plots showing significant places × treatment interaction*

Plot	*r*		*R*	Regression equation [1]	Standard error of estimate
	Soil phosphorus	Exchangeable calcium	Soil phosphorus and exchangeable calcium		
NPKCa	0.2033	0.1942	0.2567	$0.5181+0.0082x+0.0668x_1$	0.0965
NPK	.3022	.1739	.3237	$.4978+.0132x+.0050x_1$	.0930
NP	.4987**	.1924	.5076*	$.4456+.0247x+.0044x_1$	.0920
N	.6290**	.0827	.6306**	$.3191+.0326x-.0023x_1$	.0916
P	.2430	.0831	.2455	$.5420+.0091x+.0012x_1$	.0783
Mean	.5380**	.1258	.5590*	$.4399+.0214x+.0007x_1$	.0690

[1] x=Soil phosphorus; x_1=exchangeable calcium.

[7] Table not shown, but is available at the Mississippi Experiment Station.

*=Significant at odds of 19:1; **=significant at odds of 99:1; †=significant interception of treatment × places at odds of 19,1; ††=significant interaction of treatment × places at odds of 99:1.

phorus in the greens from the N and NP plots as well as the mean phosphorus increased significantly as the soil phosphorus increased. The closest relation between soil phosphorus and that in the greens was shown by the data from the nitrogen plots. The multiple correlation coefficients for soil phosphorus and exchangeable calcium which were significant were only slightly greater than the simple coefficients for soil phosphorus.

Other soil properties as studied had less effect on the phosphorus in the greens than did exchangeable calcium. Simple correlation coefficients showed a negative effect of organic matter on the mean phosphorus and on that of the greens from the N and P plots, and a positive effect on the phosphorus in the greens from the NP, NPK, and NPKCa plots. Multiple coefficients were but slightly larger than the simple coefficients for soil phosphorus, suggesting that little or no information could be gained by the multiple studies.

Covariance Analyses

Multiple correlation coefficients indicated that soil phosphorus and exchangeable calcium were more closely related to the mean phosphorus in the greens than were soil phosphorus and organic matter or soil phosphorus and pH. Hence, covariance analyses were made to study the effects of these soil properties on the variation in the plant phosphorus attributed to place. The results of the analyses made for the greens grown on the check and NKCa plots are shown in table 19. The *F* value 9.00** for place on the check plots was reduced to 6.75** when the means were adjusted on the basis of soil phosphorus; to 8.67** when adjusted on the basis of pH; and to 5.67** when adjusted on the basis of soil phosphorus and exchangeable calcium. The soil phosphorus accounted for more of the variation due to place than did the other soil properties studied.

In a similar study of the NKCa plots, where normal growth was expected with no phosphorus added, the *F* value for place was 6.55**. This value was reduced to 3.91** when the means were adjusted on the basis of soil phosphorus; to 6.19** when adjusted on the basis of pH; and to 3.75** when adjusted on the basis of soil phosphorus and exchangeable calcium. Soil phosphorus accounted for approximately 40 percent of the variation attributed to place when plots received NKCa treatments, whereas it accounted for only 25 percent when plots were not fertilized. The greater variation within the check plots unaccounted for by soil phosphorus suggests that some of the variation due to place might have been the result of differences in growth between the NKCa and check plots.

A covariance analysis of the data from the N plots was also made, since the multiple coefficient (0.6306**) for soil phosphorus and exchangeable calcium (table 18) was greater than the corresponding coefficient determined for the NKCa plots. The adjusted *F* value for place was, however, still highly significant.

**Significant at odds of 99:1.

TABLE 19.—*Covariance analyses of the phosphorus content of turnip greens from the check and NKCa plots, showing the effects of soil phosphorus, hydrogen-ion concentration (pH), and exchangeable calcium in variation due to place*

Plot	Source of variation	Variance of P content of greens (Y)				Error of estimate based on soil phosphorus (X)				Error of estimate based on pH (X_1)				Error of estimate based on soil phosphorus and exchangeable calcium (X^2)			
		Degrees of freedom	SY^2	Mean square	F.	Degrees of freedom	$SY^2-\frac{(SXY)^2}{SX^2}$	Mean square	F.	Degrees of freedom	$SY^2-\frac{(SX_1Y)^2}{SX_1^2}$	Mean square	F.	Degrees of freedom	R^2	$(1-R^2)SY^2$	Mean square	F.
Check	Total	55	0.618447			54	0.495244			54	0.617622			53	0.2883	0.440115		
	Place	27	.554546	0.020539	9.00**													
	Error	28	.063901	.002282		27	.063901	0.002367		27	.063901	0.002367		26	0	.063901	0.002458	
	Difference for testing adjusted means.					27	.431343	.015976	6.75**	27	.553721	.020508	8.67**	27		.376214	.013933	5.67**
NKCa	Total	55	.708763			54	.474563			54	.695803			53	.3568	.458876		
	Place	27	.61056	.022613	6.55**													
	Error	28	.096707	.003454		27	.096707	.003582		27	.096707	.003582		26	0	.096707	.003720	
	Difference for testing adjusted means.					27	.377856	.013995	3.91**	27	.599096	.022189	6.19**	27		.359169	.013303	3.57**

**Significant at odds of 99:1.

EFFECT OF RAINFALL AND IRRIGATION

As stated previously, records were secured of the rainfall during the growing period of each crop. The relations between the total rainfall and the average calcium and phosphorus content of the greens grown in the same place but in different seasons, or in different years, or both, were studied. The results, presented in table 20, do not show any consistent effect of rainfall on the average calcium and phosphorus content of the greens either for season or for year.

Correlation coefficients were employed to study the relation between the calcium and phosphorus in the greens and rainfall on the check plots. The coefficient for calcium (0.1527) as well as that for phosphorus (0.0361) indicated that rainfall was a minor factor in the variation due to place.

TABLE 20.—*Effect of rainfall in different seasons, at the same place, and the effect of irrigation on the calcium and phosphorus content of turnip greens*

Location	Spring, 1939			Fall, 1939			Spring, 1940			Fall, 1940		
	Rainfall	Average Ca content	Average P content	Rainfall	Average Ca content	Average P content	Rainfall	Average Ca content	Average P content	Rainfall	Average Ca content	Average P content
	Inches	*Per-cent*	*Per-cent*	*Inches*	*Per-cent*	*Per-cent*	*Inches*	*Per-cent*	*Per-cent*	*Inches*	*Per-cent*	*Per-cent*
Blairsville, Ga	10.32	3.17	0.601				5.46	3.03	0.549			
Experiment, Ga	11.11	2.47	.565							4.67	2.82	0.440
Crystal Springs, Miss				5.67	2.00	0.666	14.28	2.13	.520			
Poplarville, Miss	4.42	2.40	.492	4.42	2.12	.419	11.38	1.99	.557			
Stoneville, Miss				4.12	2.83	.720	9.46	2.88	.697			
Perkins, Okla	5.59	2.67	.516				5.41	2.97	.487			
Woodward, Okla	5.87	3.17	.463				2.59	3.24	.549			
Do[1]							3.23	3.46	.606			
Winter Haven, Tex.[1]				2.94	2.34	.658				2.00	2.21	.648
Norfolk, Va				9.56	2.29	.516				10.77	2.71	.515

[1] Crops were also irrigated.

The effect of rainfall on the NPKCa plots was also studied. These plots were selected because it seemed likely that the effects of rainfall on the calcium content of the greens might be more apparent in the plots having a complete fertilizer. The *F* value for the variation due to place was 16.61**. This value was reduced to 15.86** when the means were adjusted for total rainfall. When the phosphorus content of the greens was similarly studied, the *F* value for the variation due to place was 8.87**. Adjusting the means for total rainfall reduced the *F* value to 8.14**. Thus rainfall seems to account for only a small part of the variation in the calcium and phosphorus content of the greens due to place.

Irrigation increased the calcium and phosphorus content of turnip greens grown the same season at the same place (Woodward) on irrigated and nonirrigated plots. The *F* value for irrigation in an analysis of variance of the calcium data was 15.96** and in a similar analysis of the phosphorus data, 50.50**.

YIELD

Yield records were taken in 12 of the 30 experiments and for 1 crop at Heavener, Okla., which was not analyzed for minerals.

Eleven of the crops were grown in 1940. The yields for these experiments, their means, and the standard deviation are given in table 21. The average yield ranged from 61.74 gm. per foot of row at Experiment, Ga., to 358.46 gm. at Perkins, Okla. Significant treatment effects are listed in table 22. The application of nitrogen produced a highly significant increase in yield in 8 of the 13 experiments. At one place only (Woodward) was there a significant decrease due to nitrogen and this was on the nonirrigated plots. The yield at Blairsville was significantly increased by P and K and the interaction effects of NP and NK were positive. Potassium also significantly increased the yield at Norfolk. Significant positive interaction effects were given by PCa and PKCa at Woodward and by NPKCa at College Station.

The average effects of treatment on yields for the 13 experiments and the 3 error groups, and the *F* values for the analyses of variance are given in table 23. Nitrogen had the greatest effect of any of the fertilizer treatments. It produced an average increase in yield of 72.71 gm. per foot of row. There was an interaction of N $\times$ places in all groups. Potassium significantly increased the yield in the combined analysis, and in the low- and medium-error groups. The interaction of K $\times$ places was significant in the low-error group. Phosphorus produced a significant increase in yield in the low-error group and gave a significant treatment $\times$ places interaction in the medium-error group. Calcium had a significant positive effect in the low-error group. There were significant treatment $\times$ places interactions for NP and NK in the low-error group, and for PCa and P in the medium-error group. The *F* values from the analyses of variance show that place accounted for much more of the variation than did treatment, although the latter was highly significant.

As it seemed possible that the negative effect of N on the Ca and P in the greens might have been due to the increased yield resulting from the N treatment, a covariance analysis was made adjusting the mean calcium and phosphorus in the greens on the basis of yields (table 24). The calcium and phosphorus data for Iowa Park and Heavener were eliminated. It was also necessary to eliminate from the phosphorus study the data from experiments in which N significantly increased the phosphorus content of the greens. Results of the covariance analyses shown in table 24 indicate that in these experiments the difference in the calcium and phosphorus content of greens grown on nitrogen plots and those grown on plots receiving no fertilizer could be accounted for by increased yield. Attention, however, should be called to the fact that increased yields are not necessarily accompanied by a decrease in calcium and phosphorous in the greens, especially the latter. Thus, at Stoneville, the addition of nitrogen produced a large increase in yield as well as a significant increase in the phosphorous of the greens, while at Norfolk an increase in yield occurred with no decrease in either calcium or phosphorus in the plant. Differences in yield also failed to account for the significant variation in the calcium and phosphorus content of the greens from the experiments where yield records were taken.

TABLE 21.—*Average yield of turnip greens grown by a factorial design of 16 duplicate fertilizer treatments in 13 experiments*

TABLE 21.—*Average yield of turnip greens grown by a factorial design of 16 duplicate fertilizer treatments in 13 experiments*

Experiment No.	Location	Year	Average yield per foot of row from duplicate plots fertilized with—									
			NPKCa	NPK	NPCa	NP	NKCa	NK	NCa	N	PKCa	PK
			Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*
2	Blairsville, Ga.	1940	184.20	158.75	84.35	107.05	120.65	95.25	70.75	52.65	66.20	45.40
4	Experiment, Ga.	1940 [1]	72.60	60.80	47.20	76.20	70.05	57.15	66.20	53.50	62.60	58.05
7	Crystal Springs, Miss.	1940	308.35	213.35	233.35	146.65	255.00	226.65	231.65	200.00	30.35	19.75
11	Poplarville, Miss.	1940	276.00	288.00	220.15	236.00	224.70	282.80	223.15	248.00	59.00	43.80
13	Stoneville, Miss.	1940	449.15	476.65	401.65	389.00	524.00	370.00	425.00	467.50	154.35	148.20
17	Perkins, Okla.	1940	373.75	408.25	333.80	348.35	357.45	314.80	355.70	377.35	401.00	374.65
19	Woodward, Okla.	1940	111.55	105.25	117.00	124.25	115.20	91.65	151.50	117.05	156.95	142.45
20	...do [2]	1940	311.15	191.45	206.85	146.05	140.60	305.70	257.65	185.85	129.75	112.45
15-A [3]	Heavener, Okla.	1940	157.85	129.70	114.30	82.55	89.80	83.25	98.90	69.85	36.30	62.40
24	College Station, Tex.	1940 [1]	245.20	270.75	205.55	279.20	206.95	244.75	222.50	208.40	249.45	289.20
25	Iowa Park, Tex.	1939 [1]	154.20	280.95	270.75	267.30	231.70	220.05	310.75	227.60	221.80	236.75
27	Winter Haven, Tex.	1940 [1]	234.25	204.65	184.15	205.25	232.65	282.55	247.95	239.50	193.30	213.65
30	Norfolk, Va.	1940 [1]	180.50	151.00	163.50	130.00	145.50	150.00	131.50	133.50	90.00	81.50

Experiment No.	Location	Year	Average yield per foot of row from duplicate plots fertilized with—Continued						Mean	Standard Deviation	Odds of—	
			PCa	P	KCa	K	Ca	Check			19:1	99:1
			Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Percent*			
2	Blairsville, Ga.	1940	47.20	40.85	43.55	39.00	36.30	46.30	77.40	20.87	44.46	63.24
4	Experiment, Ga.	1940 [1]	59.90	56.95	58.05	52.65	67.00	68.95	61.74	18.02	38.38	53.09
7	Crystal Springs, Miss.	1940	21.65	28.35	30.00	22.35	34.85	10.00	125.76	65.77	140.15	193.83
11	Poplarville, Miss.	1940	52.80	68.80	58.15	95.30	34.80	93.00	156.53	37.14	79.14	109.43
13	Stoneville, Miss.	1940	169.20	177.30	145.65	197.50	134.80	156.65	299.16	79.56	169.53	234.47
17	Perkins, Okla.	1940	319.35	366.50	380.15	348.35	352.00	323.85	358.46	55.55	118.37	163.71
19	Woodward, Okla.	1940	156.95	137.90	148.80	127.90	123.40	112.45	127.52	25.50	54.33	75.15
20	...do [2]	1940	142.40	130.65	97.10	146.00	88.90	124.30	169.87	46.34	98.74	136.58
15-A [3]	Heavener, Okla.	1940	42.65	27.25	60.80	38.10	34.45	31.75	72.49	27.79	59.23	81.88
24	College Station, Tex.	1940 [1]	270.75	177.20	225.40	185.65	198.50	296.25	235.98	44.45	94.72	130.98
25	Iowa Park, Tex.	1939 [1]	272.45	226.40	283.60	354.65	288.35	377.10	264.03	70.97	151.23	209.13
27	Winter Haven, Tex.	1940 [1]	172.50	159.05	230.35	149.60	218.05	162.85	208.14	35.19	74.98	103.72
30	Norfolk, Va.	1940 [1]	64.50	62.50	70.00	87.50	88.00	60.50	111.88	17.50	37.31	51.56

[1] Fall crops. Undesignated crops were grown in the spring.

[2] Plots were irrigated.

[3] No mineral analyses were made on the 1940 crop at Heavener.

TABLE 22.—*Significant effects of the 16 fertilizer treatments on the yield of turnip greens from 13 experiments*

Experiment No.	Location	Average effect of indicated fertilizer treatment on yield per foot of row															Odds of—	
		NPKCa	NPK	NPCa	NP	NKCa	NK	NCa	N	PKCa	PK	PCa	P	KCa	K	Ca	19:1	99:1
		Gm.	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*		
2	Blairsville, Ga				+20.07*		+27.57**		+63.61**				+28.69**		+33.44**		15.72	22.36
4	Experiment, Ga																13.57	18.77
7	Crystal Springs, Miss								+202.29**								49.55	68.53
11	Poplarville, Miss								+186.64**								27.98	38.69
13	Stoneville, Miss								+277.41**								59.94	82.90
17	Perkins, Okla								−21.67*								41.85	57.88
19	Woodward, Okla								+96.94**	+39.23*		+48.52**					19.21	26.57
20	do								+61.56**								34.91	48.29
15-A	Heavener, Okla																20.94	28.95
24	College Station, Tex	+46.35**															33.49	46.31
25	Iowa Park, Tex								+41.15**						+15.25*		53.47	73.94
27	Winter Haven, Tex								+72.63**								26.51	36.67
30	Norfolk, Va																13.19	18.23

*=Significant at odds of 19:1; **=significant at odds of 99:1.

The regression equation using mean percentage of calcium as a dependent factor (Y) on exchangeable calcium (X) and yield (X_1) is $Y=2.093+0.1208X+0.0005X_1$. The multiple correlation coefficient, $R=0.7292$*, is but slightly larger than the simple correlation coefficient, $r=0.7138$**, for exchangeable calcium. The regression equation using average percentage of calcium from the N plots as a dependent factor on the same independent factors is $Y=2.2396+0.1027X-0.0007X$. For these plots $R=0.6069$ where $r_{xy}=0.5816$ and $r_{x1}y=-0.2830$.

Regression equations using percentage of phosphorus as a dependent factor were not studied because the variation in the effect of N on percentage of phosphorus limited homogeneous data to a few experiments.

TABLE 23.—*Results of the total experiments and of the error groups, showing the average yield of turnip greens per foot of row, the average effects of the fertilizer treatments on yield per foot of row, and the F values from the variance analysis of each group*

Fertilizer treatment	Total group (13 experiments [1])		Low-error group (5 experiments [2])		Medium-error group (5 experiments [3])		High-error group (3 experiments [4])	
	Average yield, 26 plots	Average effect of treatment, 208 plots	Average yield, 10 plots	Average effect of treatment, 80 plots	Average yield, 10 plots	Average effect of treatment, 80 plots	Average yield, 6 plots	Average effect of treatment, 48 plots
	Gm	*Gm*	*Gm*	*Gm*	*Gm*	*Gm*	*Gm*	*Gm*
NPKCa	235.29	+5.36	141.34	+3.84	288.07	+17.21*†	303.90	−11.85
NPK	226.12	+6.73	121.10	+3.62	272.62	+5.74	325.65	+13.58
NPCa	198.66	−3.56	105.27	−1.29	230.10	+3.46	301.92	−19.06
NP	195.22	+3.98	104.01	+7.29†	242.97	−2.72	267.65	+9.63
NKCa	208.79	−1.82	108.24	+2.08	232.47	−7.27	336.90	+.75
NK	209.58	+5.79	95.46	+4.41††	286.12	+5.86	272.23	+7.98
NCa	214.86	+3.72	103.77	+3.26	261.39	−5.53	322.47	+19.88
N	198.60	+72.71**††	85.31	+35.71**††	252.02	+64.85**††	298.37	+147.49**††
PKCa	142.39	+.34	82.41	+2.32	206.50	+5.64	135.50	−11.80
PK	140.59	+8.92	77.96	+6.02	206.75	+14.87	134.70	+3.85
PCa	137.87	+2.85	74.24	−1.15	191.56	+8.26	154.43	+.50
P	127.67	+1.89	65.09	+12.44*†	180.44	+3.16††	144.02	−17.84
KCa	140.89	−1.01	76.24	+1.25	198.23	−1.40	153.08	−4.11
K	141.89	+12.32*	69.03	+12.53**††	184.98	+17.35*	191.50	+3.59
Ca	130.72	+3.30	69.83	+9.92*	178.45	−4.90	152.67	+5.94
Check	143.38		63.99		200.05		181.25	
Mean	174.53		90.21		225.80		229.64	
Standard deviation	46.40		22.21		44.33		72.33	
Odds at 19:1	27.44	9.70	21.16	7.48	42.26	14.94	88.98	31.46
Odds at 99:1	37.93	13.41	29.27	10.35	58.43	20.66	123.06	43.51
Treatment *F* values:								
Residual as error	18.34**		9.99**		7.23**		7.20**	
Place × treatment as error	5.80**		.79		2.58**		2.09*	
Place *F* values:								
Residual as error	128.46**		51.07**		105.58**		51.42**	
Place × treatment as error	40.63**		4.04**		37.61**		14.92**	
Replication *F* value:								
Residual as error	1.75		1.87		2.80*		1.08	

[1] Factorial experiment Nos.: 2, 4, 7, 11, 13, 17, 19, 20, 15-A, 24, 25, 27, 30.
[2] Factorial experiment Nos.: 2, 4, 15-A, 19, 30.
[3] Factorial experiment Nos.: 11, 17, 20, 24, 27.
[4] Factorial experiment Nos.: 7, 13, 25.

*=Significant at odds of 19:1; **= significant at odds of 99:1; †=significant interaction of treatment × places at odds of 19:1; ††=significant interaction of treatment × places at odds of 99:1.

TABLE 24.—*Covariance analyses indicating the relationship of yield to the calcium and phosphorus content of turnip greens*

Source of variation	Calcium [1]								Phosphorus [2]							
	Variance of calcium content of greens (y)				Error of estimate based on average yields (x)				Variance of phosphorus content of greens (y)				Error of estimate based on average yields (x)			
	Degrees of freedom	Sy^2	Mean square	F	Degrees of freedom	$Sy^2-\frac{S(xy)^2}{Sx^2}$	Mean square	F	Degrees of freedom	Sy^2	Mean square	F	Degrees of freedom	$Sy^2-\frac{S(xy)^2}{Sx^2}$	Mean square	F
Total	21	88.6209	----	----	----	----	----	----	15	0.9017	----	----	----	----	----	----
Place	10	69.8770	----	----	----	----	----	----	7	.6049	----	----	----	----	----	----
N-level	1	11.3868	11.3868	**15.48	----	----	----	----	1	.1532	0.1532	*7.47	----	----	----	----
Error	10	7.3571	0.7357	----	9	2.9138	0.3238	----	7	.1436	.0205	----	6	0.0719	0.0120	----
N+error	11	18.7439	----	----	10	4.1482	----	----	8	.2908	----	----	7	.0770	----	----
Difference for adjusting means	----	----	----	----	1	1.2344	1.2344	3.81	----	----	----	----	1	.0051	.0051	(3)

[1] Experiments used in calcium analysis: 2, 4, 7, 11, 13, 17, 19, 20, 24, 27, 30.
[2] Experiments used in phosphorus analysis: 2, 7, 11, 17, 19, 20, 27, 30.
[3] Not significant.
*=Significant at odds of 19:1; **=significant at odds of 99:1; †=significant interaction of treatment × places at odds of 19:1; ††=significant interaction of treatment × places at odds of 99:1.

DISCUSSION

The results from the data which have been presented in this study show the effects of the same fertilizer treatments on the calcium and phosphorus content of turnip greens when they were grown under a variety of environmental conditions. It is to be expected, therefore, that the effects of the fertilizer treatments would vary with the place where the greens were grown. In some respects, however, there was a rather striking similarity between places in the effects of certain treatments, notably those for nitrogen, calcium, and phosphorus. Nitrogen significantly decreased the calcium content of the greens in 24, and the phosphorus content in 12, of the experiments. This is in accord with the effect of nitrogen fertilizers on pasture grasses reported by several investigators and reviewed by Vandecaveye (*26*). Other investigators (*28*, *9*), have noted the depressing effect of applied nitrogen on the calcium content of plants, but have reported an increase in the phosphorus content. Since there were 6 experiments in which the phosphorus was significantly increased by nitrogen fertilizer, it would seem that its effect on phosphorus was more dependent upon factors associated with place, including other soil factors, than was its effect on calcium.

The increase in the calcium content of the greens from applied calcium confirms the results of previous studies on vegetables (*18*, *21*), and other plants (*17*, *20*). The greatest responses to added calcium were observed when the greens were grown on soils containing the least calcium. When calcium was added to the soil it also showed a tendency to increase the phosphorus content of the greens, although the results were not consistent. Varying effects of applied calcium on the phosphorus content of plants have been reported by Ames and Schollenberger (*2*) and by Beeson (*6*), the results obtained depending upon the soil in which the plants were grown.

The effect of phosphorus on the phosphorus content of the greens was almost as great as that for calcium on the calcium content of the greens. Eighteen of the 27 experiments showing an increase in phosphorus gave significant increases. The soils in all of the 18 experiments were low in phosphorus. There have been many reports concerning the effect of phosphorus fertilizers on the phosphorus in plants which would seem to agree with these findings. Of particular interest are those of Bishop (*7*), Brown (*8*), and Wimer (*29*). In the majority of the experiments, the combination of phosphorus and nitrogen produced a positive interaction effect on the phosphorus in the greens, the effect being highly significant in the total experiments and in the low-error group. In this connection it is interesting to note that the interaction effect of NP was greatest on the low organic-matter soils (table 17).

The effect of applied phosphorus on the calcium content of the greens like that of calcium on the phosphorus content of the greens, seemed to depend upon the soil in which the greens were grown. The tendency of phosphorus was to decrease the calcium, there being a significant negative effect of three places and in the total experiments. A significant increase in phosphorus occurred, however, at three places.

The effect of place is the most striking result brought out by the analysis of the data on the calcium and phosphorus content of the greens. The variation in the average calcium and phosphorus in the

greens associated with place is graphically presented in figures 2 and 3, respectively. In the low-error groups of the variance analyses the effect of place was 13 times greater for calcium and 20 times greater for phosphorus than was the effect of treatment, although the latter had a highly significant effect. The much greater influence of place when compared to fertilizer treatment, on the calcium and phosphorus content of clover, has been reported by Myers and Metzger (*16*).

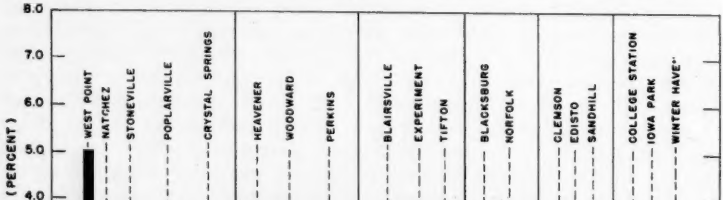

FIG. 2.—Average calcium content in each of 30 crops of turnip greens.

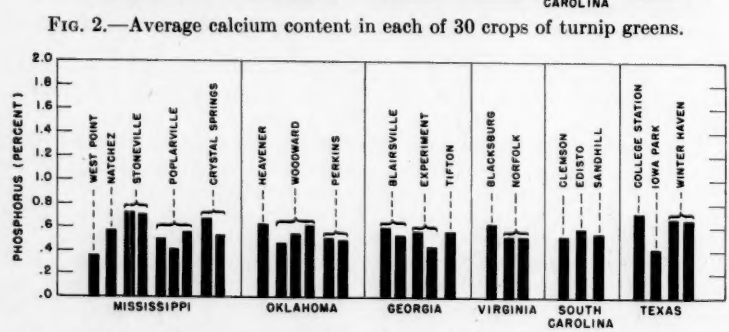

FIG. 3.—Average phosphorus content in each of 30 crops of turnip greens.

In a study of the composition of bluegrass in different parts of Ohio, Forbes, Whittier, and Collision (*12*) found that, "While the mineral content of vegetable crops is without doubt the resultant of a considerable number of varying factors, the most important of these is the composition of the soil." There can be no doubt that the composition of the soil is one of the most important factors affecting the mineral content of vegetables, and it would have been desirable to make much more complete investigations of this relationship at each place than was done. Such complicated studies were not feasible, but some of the soil properties which were studied indicated that soil had a more marked effect than did fertilizer treatments. When the soils were classified according to the amount of calcium or phosphorus

present and the effects of the fertilizer treatments determined for the different classes, it was found that soil calcium had a greater effect on the calcium content of the greens, and soil phosphorus on the phosphorus content of the greens, than did the respective minerals applied as fertilizer (tables 8 and 16). The greens grown on the high-calcium soils contained 33 percent more calcium on an average than those grown on the low-calcium soils. The greatest effect for applied calcium was shown by the trace-calcium soils, the increase being 0.135 percent. The average phosphorus content of the greens from the high-phosphorus soils was about 34 percent greater than that from the low-phosphorus soils. Only the low-phosphorus soils gave any significant effect for applied phosphorus, the increase in the phosphorus content of the greens being 0.0467 percent. In this connection, however, attention should be called to the differences in the soil levels of calcium and phosphorus as compared with the amount added as fertilizer. Differences between the calcium content of the trace- and high-calcium soils were about 2,000 pounds per acre, whereas only 120 pounds of calcium per acre was added as fertilizer. The difference between the low- and high-phosphorus soils was about 300 pounds per acre and only 60 pounds of P_2O_5 was added as fertilizer.

In the study of the relationships between soil properties and the calcium content of the greens the positive relationship between exchangeable calcium and plant calcium was the most significant. The experiments at West Point furnish a striking illustration of this observation. The West Point greens contained over 44 percent more calcium than those from any other place, and the amount of exchangeable calcium in the soil was much greater than that of any other place. The correlation coefficients for exchangeable calcium of the soil and the phosphorus in the greens were positive but not significant (table 18). The greens, however, which were grown in soil with an extremely high exchangeable calcium content had a low phosphorus content.

Although the rapid test for measuring available soil phosphorus is not as accurate as the test for measuring exchangeable calcium in the soil, the correlation coefficient showed a significant relationship between the available soil phosphorus level and the phosphorus content of the greens. The closest relationship between soil and plant phosphorus was given by the data from the nitrogen plots. This suggests that insufficient nitrogen in the soil was the limiting factor in the utilization of soil phosphorus by the plant.

Exchangeable calcium and hydrogen-ion concentration are so closely related that similar trends in effects on the mineral composition of the greens were to be expected. Both the correlation and the covariance analyses showed that exchangeable calcium has a greater effect than hydrogen-ion concentration on the calcium and phosphorus content of the greens.

Outstanding effects for organic matter were not demonstrated by the analysis of the data obtained in these investigations, although some interesting results were observed. The average calcium and phosphorus content of the greens increased with increased organic matter. The variation in each of the two minerals due to place was considerably less in the high organic-matter soils than it was for those lower in organic matter (tables 9 and 17).

A study of the various effects of the fertilizer treatments in the experiments which were repeated in successive seasons at the same location indicates that weather conditions may have had as great an influence as soil on the mineral composition of the plant. Thus the experiment at Norfolk in the fall of 1939 showed no effect on the phosphorus in the greens for any treatment, but the experiment for the fall of 1940 at the same place showed significant effects for four treatments (table 14). Even greater differences in the effects of the fertilizer treatments on calcium were found between the fall 1939 and the spring 1940 experiments at Stoneville. There were no significant effects for the fall experiment, but there were six significant effects for the spring experiments (table 6).

From an analysis of the data, rainfall did not show any consistent effect on the calcium and phosphorus content of turnip greens. The many other factors related to place which caused variations in the mineral content of the greens masked the effects which rainfall may have had. When, however, the greens were grown at the same place, during the same season, thereby eliminating variations due to place and season, it was found that irrigation significantly increased the calcium and phosphorus content of turnip greens. This is in agreement with the findings of Daniel and Harper (*10*) for phosphorus but not for calcium. They found that the phosphorus in hay increased with high rainfall but that the calcium decreased.

Both place and fertilizer treatments had an important effect on yield, but the effect of place was much greater than that of fertilizer treatments. It seems probable that the principal factors related to place which caused variations in yield were soil fertility and rainfall, but these factors could not be adequately studied because the data were insufficient.

It was to be expected that the application of nitrogen would increase the yield of turnip greens, as the majority of southern soils, including those on which the greens were grown, are rather low in nitrogen. The covariance analyses indicate that the decrease in the percentage of calcium and phosphorus in the greens resulting from the use of nitrogen fertilizer is associated with the increase in the amount of plant tissue (table 24). The results at Stoneville and Norfolk, however, demonstrate that an increase in yield is not always accompanied by a decrease in the calcium and phosphorus content of the plant. It is probable that results comparable to these would have been secured in other experiments had complete yield data been available for analysis. It should be noted also that while nitrogen decreased the calcium and phosphorus in the greens, increased yields resuled in an increase in the amount of plant calcium and phosphorus produced per foot of row.

The data on yield and on the calcium and phosphorus content of the greens (tables 5, 13, and 21) show that the variation due to place would still be significant when the effect of yield on the calcium and phosphorus content of the greens was eliminated. Although the data on yield are incomplete, the *F* values from the covariance analyses of the calcium and phosphorus in the greens grown on the check, NPK, and KNCa plots support the foregoing statement (tables 12 and 19).

SUMMARY AND CONCLUSIONS

Nineteen nonfactorial experiments were conducted at 12 localities, and 30 factorial experiments were conducted at 19 localities to determine the effects of place and of fertilizer treatments on the calcium and phosphorus content of turnip greens. Certain soil factors and rainfall were also studied in the factorial experiments. The plan for the nonfactorial experiments was to use a uniform fertilizer treatment at each place, the treatment depending upon the best soil practices in that locality. There were 10 replicates in each experiment. For the factorial experiments a $2\times2\times2\times2$ design was used for applications of N, P, K, and Ca in all possible combinations at a high and a low level for each nutrient. The same amount of each fertilizer was used in all experiments.

Seed of the variety Seven Top from the same source, as well as uniform methods of planting and fertilizing, were used. Soil samples were taken from 29 of the sites where the turnip greens were grown and were analyzed for calcium, total exchange capacity, exchangeable calcium, phosphorus, magnesium, organic matter, and pH values.

Samples of turnip greens harvested at a good marketable stage were prepared for analysis by washing in tap and distilled water, drying, and grinding in a porcelain ball mill. The whole plant was used with the exception of damaged leaves, a small portion of the stems next to the root, and the root. Methods of the Association of Official Agricultural Chemists were employed for the determination of calcium and phosphorus.

The results of the nonfactorial and of the factorial experiments were analyzed statistically. The analysis of variance was applied to the data from the factorial experiments. The method of Yate was used to determine the effect of each fertilizer treatment.

In both the nonfactorial and factorial experiments, there was a marked variation in the calcium and phosphorus content of the greens grown at different places. Significant differences in both elements were also observed in vegetables grown at the same place but in different seasons.

Results from the factorial experiments showed that conditions associated with place caused from 13 to 20 times more variation in the calcium and phosphorus content of greens than did the fertilizer in the amounts used, and that the effects produced by the different treatments varied with the season.

The soil properties total calcium, total phosphorus, exchangeable calcium, hydrogen-ion concentration, and organic matter were studied. Covariance and correlation analyses showed that these properties of the soil accounted for an important part, but not all, of the variation in the mineral content that was attributed to place. Results noted were as follows:

(1) The calcium content of the greens increased significantly as exchangeable calcium, pH, and the level of soil calcium increased.

(2) Exchangeable calcium did not have a significant effect on the phosphorus content of the greens.

(3) There was a small but not significant increase in both the calcium and phosphorus content of greens as the organic matter of the soil increased.

(4) The phosphorus content of greens grown on high-phosphorus soils was significantly greater than that of greens grown on low-phosphorus soils.

The data on rainfall showed no consistent relationship between the total amount of rainfall and the calcium and phosphorus content of the greens. At Woodward, however, both the plant calcium and phosphorus were significantly increased by irrigation.

The effects of fertilizer treatments, though not as great as that of place, were highly significant. The following effects were noted:

Nitrogen produced the most marked effect on the mineral content of the greens. It significantly decreased the calcium content of the greens in 24 of the 30 experiments. The average depression of calcium by nitrogen was approximately 0.36 percent. The effect of nitrogen on the phosphorus content of greens varied with season as well as with place. In general, the effect was a negative one, although in 6 experiments the phosphorus was significantly increased. There was a highly significant interaction for the effect of nitrogen on both the calcium and the phosphorus content of the greens, emphasizing the fact that the effects produced by nitrogen on different soils were not uniform.

Calcium applied as gypsum increased calcium in the greens on an average of 0.06 percent. The effect produced by Ca, however, varied greatly in the different experiments. Calcium showed a tendency to increase the phosphorus content of the greens, but the increase was significant in only 3 experiments and was not significant for the average of 29 experiments.

Applied phosphorus decreased the average plant calcium 0.046 percent, but it increased the average plant phosphorus 0.0537 percent. This was the greatest effect produced by any treatment on the phosphorus content of the greens. Both effects were highly significant and were characterized by significant interactions of treatment $\times$ places.

Potassium had no marked effect on either the calcium or the phosphorus. There were a few experiments, however, in which significant effects were produced.

The NK treatments had a significant negative interaction effect on both calcium and phosphorus. The effect on calcium was more pronounced than the effect on phosphorus.

The NP treatments had a significant positive interaction effect on phosphorus, but a significant negative effect on calcium. The variation in this effect caused by place was greater for phosphorus than for calcium.

Soils were classified according to the amount of calcium, phosphorus, and organic matter present, and the effects of the fertilizer treatments in each classification were determined. Treatments, other than N and P, produced greater effects on plant calcium when soils were low in calcium. The typical effects of N and of P, and the interaction effects of NP on phosphorus, were also more intense on low phosphorus-low calcium soils than on low phosphorus-high calcium soils. Applied P had no effect on the phosphorus of the greens grown on high-phosphorus soils.

Yield records were obtained for 13 experiments. The average yield was 174.53 gm. per foot of row. The significance of both main effects and interaction effects varied with the place. The low-error experi-

ments showed that yield was increased significantly by the applications of N, P, K, and Ca, but the greatest increase was produced by N. This average increase was approximately one-third of the total yield. The variation in yield caused by place was about seven times greater than that caused by applications of fertilizer treatments.

LITERATURE CITED

(1) Allison, L. E.
1935. organic soil carbon by reduction of chromic acid. Soil Sci. 40: 311–320.

(2) Ames, J. W., and Schollenberger, C. J.
1924. the availability of phosphorus in calcareous and non-calcareous soils. Ohio Agr. Expt. Sta. Bul. 380, pp. 215–242.

(3) Association of Official Agricultural Chemists.
1930. official and tentative methods of analysis . . . Ed. 3, 593 pp., illus. Washington, D. C.

(4) Association of Official Agricultural Chemists.
1935. official and tentative methods of analysis . . . Ed. 4, 710 pp., illus. Washington, D. C.

(5) Association of Official Agricultural Chemists.
1940. official and tentative methods of analysis . . . Ed. 5, 757 pp., illus. Washington, D. C.

(6) Beeson, K. C.
1941. the mineral composition of crops with particular reference to the soils in which they were grown. a review and compilation. U. S. Dept. Agr. Misc. Pub. 369, 164 pp., illus.

(7) Bishop, E. R.
1934. the calcium and phosphorus content of some alabama vegetables. Jour. Nutr. 8: 239–245.

(8) Brown, B. A.
1932. the effects of fertilization on the chemical composition of vegetation in pastures. Amer. Soc. Agron. Jour. 24: 129–145.

(9) ———
1940. the chemical composition of pasture species of the northeast region as influenced by fertilizers. Amer. Soc. Agron. Jour. 32: 256–265, illus.

(10) Daniel, H. A., and Harper, H. J.
1935. the relation between effective rainfall and total calcium and phosphorus in alfalfa and prairie hay. Amer. Soc. Agron. Jour. 27: 644–652, illus.

(11) Fisher, R. A.
1934. statistical methods for research workers. Ed. 5, rev. and enl., 319 pp., illus. Edinburgh and London.

(12) Forbes, E. B., Whittier, A. C., and Collison, R. C.
1910. the mineral nutrients in blue-grass. Ohio Agr. Expt. Sta. Bul. 222, pp. 39–53.

(13) Goff, E. S.
1887. observations on root growth. N. Y. Agr. Expt. Sta. Rpt. (1886) 5: 157–165.

(14) Immer, F. R., Hayes, H. K., and Powers, L.
1934. statistical determination of barley varietal adaptation. Amer. Soc. Agron. Jour. 26: 403–419.

(15) Miles, I. E.
[1938.] rapid testing of soils for plant food deficiencies under southern conditions. Soil Sci. Soc. Amer. Proc. (1937) 2:143–150.

(16) Myers, H. E., and Metzger, W. H.
1936. the influence of superphosphate and light lime applications alone and in combination on the composition of sweet clover. Amer. Soc. Agron. Jour. 28:976–984.

(17) Naftel, J. A.
1937. soil liming investigations: iv. the influence of lime on yields and on the chemical composition of plants. Amer. Soc. Agron. Jour. 29: 537–547, illus.

(18) Parker, M. M., Hester, J. B., and Carolus, R. L.
[1933.] The effect of soil conditions on the growth and composition of certain vegetable crop plants as influenced by soil reaction. Amer. Soc. Hort. Sci. Proc. (1932) 30: 452–457, illus.
(19) Paterson, D. D.
1939. Statistical technique in agricultural research. 263 pp., illus. New York and London.
(20) Pierre, W. H., and Robinson, R. R.
1937. The calcium and phosphorus content of pasture herbage and of various pasture species as affected by fertilization and liming. Amer. Soc. Agron. Jour. 29: 477–497.
(21) Purdy, A. W.
[1940.] Effects of controlled calcium supply on carrots grown in colloidal clay cultures. Amer. Soc. Hort. Sci. Proc. (1939) 37: 799–802.
(22) Purvis, E. R., and Higson, G. E., Jr.
1939. Determining organic carbon in soils. A modification of the chromic acid reduction method. Indus. and Engin. Chem. Analyt. Ed. 11: 19–20, illus.
(23) Reder, R., Ascham, L., and Eheart, M. S.
1943. Effect of fertilizer and environment on the ascorbic acid content of turnip greens. Jour. Agr. Res. 66: 375–388, illus.
(24) Schollenberger, C. J.
1931. Determination of soil organic matter. Soil Sci. 31: 483–486.
(25) ——— and Dreibelbis, F. R.
1930. Analytical methods in base exchange investigations on soils. Soil Sci. 30: 161–173, illus.
(26) Vandecaveye, S. C.
[1941.] Effects of soil type and fertilizer treatments on the chemical composition of certain forage and small grain crops. Soil Sci. Soc. Amer. Proc. (1940) 5: 107–119.
(27) Weaver, J. E., and Bruner, W. E.
1927. Root development of vegetable crops. 351 pp., illus. New York and London.
(28) Wilkins, H. L., and Vinall, H. N.
1933. The effect of lime and of certain fertilizer constituents on the yield and composition of the herbage from pasture plats at Beltsville, Maryland. Amer. Soc. Agron. Jour. 25: 603–611, illus.
(29) Wimer, D. C.
1937. Composition of mature corn stover as affected by variety, soil type, and fertilizer treatment. Ill. Agr. Expt. Sta. Bul. 437, 23 pp. (Abstract.)
(30) Yates, F.
1937. The design and analysis of factorial experiments. Imp. Bur. Soil Sci. Tech. Comm. 35, 96 pp.

U. S. GOVERNMENT PRINTING OFFICE: 1944